CORPS OF ENGINEERS, U. S. ARMY

ENTRANCES TO CONDUITS OF RECTANGULAR CROSS SECTION

REPORT NO. 1

INVESTIGATION OF ENTRANCE FLARED IN FOUR DIRECTIONS

CWI ITEM NO. 802

CONDUIT INTAKE MODEL TESTS

TECHNICAL MEMORANDUM NO. 2-428

CONDUCTED FOR

OFFICE OF THE CHIEF OF ENGINEERS

BY

WATERWAYS EXPERIMENT STATION

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PREFACE

Investigation of the shapes of entrances to conduits of rectangular cross section was authorized by the Office, Chief of Engineers, on 6 January 1948, as part of the Civil Works Investigation program. The tests reported herein constitute the first phase of work to be accomplished under Item CW 802, Conduit Intake Model Tests, and concern entrance shapes of rectangular conduits in which the entrance was flared in four directions. Tests of entrances flared in three directions and in one direction will be the subjects of future reports.

All tests were conducted at the Waterways Experiment Station under the general direction of and in cooperation with engineers of the Office, Chief of Engineers.

CONTENTS

SUMMARY

Tests of conduit entrances reported herein were conducted with a view to developing an entrance shape that would not be damaged by cavitation and yet would be as small as possible in cross section. The effects of varying the conduit axis from normal to the face of the dam, and of varying the depth of approach channel with respect to the invert of the conduit were also investigated. Pressure measurements were made on a transparent plastic conduit, 0.283 ft wide by 0.500 ft high by 8.64 ft long, connected to a steel pressure headbay tank.

Best performance was obtained with an entrance, designated as type L, the upstream portion of which follows the elliptical curve

$$\frac{X^2}{D^2} + \frac{Y^2}{(0.32D)^2} = 1 ,$$

while the downstream portion follows the curve,

$$\frac{X^2}{D^2} + \frac{Y^2}{(0.16D)^2} = 1 ,$$

where D is the dimension of the conduit in the direction concerned. A slightly smaller entrance can be obtained by the use of a single curve with a semiminor axis of $D/3$ or $D/4$ to provide a gradual reduction in the pressure gradient. The tests also indicated that a conduit with an entrance curve shaped as above $(D/3)$ may be varied as much as 10 degrees from normal to the face of the dam without an appreciable effect upon pressures. The skewing of the axis to parallel the face of the dam, as advocated by some designers, did not accomplish the desired results. Variation of the depth of approach channel had little effect on the magnitude of pressures through the entrance. The placing of bulkhead guides near the point of curvature of the entrance had little effect on pressures in the intake.

ENTRANCES TO CONDUITS OF RECTANGULAR CROSS SECTION

INVESTIGATION OF ENTRANCE FLARED IN FOUR DIRECTIONS

PART I: INTRODUCTION

The Problem

1. Conduit entrances in high dams are subject to cavitation damage unless they are shaped so as to insure that the high velocity jet will not separate from the confining walls of the conduit. For high heads the water in the conduit may be flowing at or near spouting velocity, with a loss at the intake of most of the head available to cause flow. Under these conditions flow disturbances may cause negative pressure, and cavitation may occur with its resulting pitting of the adjacent concrete surfaces. The designer is, therefore, particularly interested in providing the proper shape at the intake to avoid cavitation damage. Another consideration in the design of conduit entrances is the desirability of making the dimensions of the entrance as small as possible to reduce costs of concrete forms and metal linings, and the size of bulkhead closure gates. It would appear that entrances to conduits should be satisfactorily designed if they conform to the curves of the free jet issuing from a sharp-edged orifice of similar proportions. Such a design is possible if the conduit is circular and normal to the upstream face of the dam. However, if the conduit is square or rectangular the design of entrance is complicated by the fact that the cross section of the jet issuing from a rectangular orifice is not rectangular but is distorted by the effect of flow at the corners.

2. Kirchoff* developed an analysis for determination of the shape of the jet issuing from a rectangular orifice of infinite length. However, the shape of the entrance with which the engineer is normally concerned is of finite length and the use of empirical curves for entrance

* H. Lamb, Hydrodynamics, 6th ed., Cambridge, England, The University Press (1932), p 98, paragraph 75.

profiles has become common practice. Professor H. A. Thomas*, formerly of Carnegie Institute of Technology, developed a procedure based on area reduction that resulted in a curved entrance falling between the extremities of the profiles of jets from circular and infinitely long orifices. Investigation of this procedure indicated that pressure conditions in entrances to conduits of square or rectangular shape were not satisfactory and led to the initiation of the series of tests reported herein.

Purpose of Tests

3. The purpose of these tests was to develop a conduit entrance shape that would be free of the danger of cavitation and as small as possible in cross section. Also, the effects of varying the conduit axis from normal to the face of the dam, and of varying the depth of approach channel with respect to the invert of the conduit were to be determined.

Experimental Apparatus

4. All tests were conducted on a model conduit 0.283 ft wide by 0.500 ft high by 8.64 ft long (fig. 1). These dimensions simulate a prototype conduit 5.667 ft wide by 10 ft high by 172.8 ft long to a scale of 1:20. The conduit was constructed of plexiglass with piezometers located at critical points along the center line and corners of the top, bottom, and sides. A large steel pressure tank was used as a headbay to permit simulation of a large range of head conditions. The conduit was maintained in a horizontal position for all tests. For those tests wherein the angle of the conduit was varied with respect to the face of the dam, the steel plate in the end of the pressure tank to which the conduit was attached was set at the desired angle (fig. 2).

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* H. A. Thomas, "Design of Bellmouths for Entrances to Conduits of Circular, Square and Rectangular Cross Sections." Report to District Engineer, Pittsburgh District, Corps of Engineers (1946).

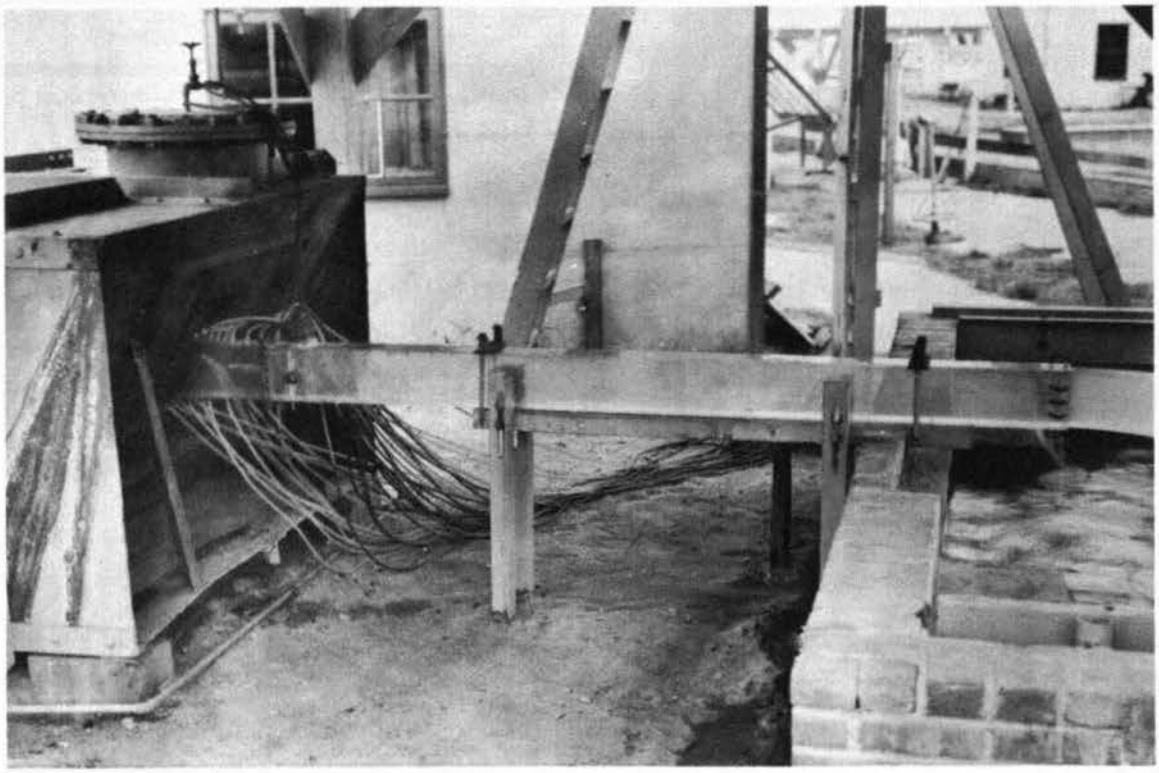

Fig. 1. Conduit and portion of pressure tank

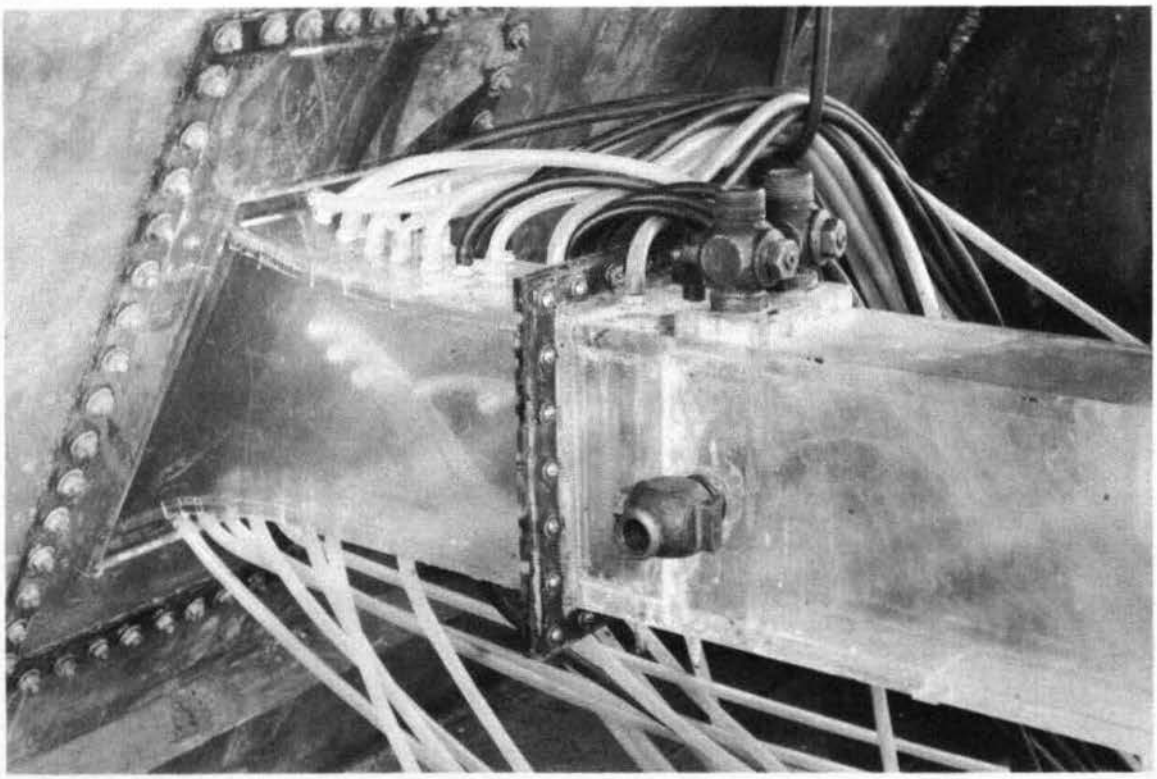

Fig. 2. Steel plate in end of pressure tank and conduit entrance

Method of Operation

5. All entrances were tested under a range of heads varying from 1.25 to 15 ft. The head was measured between the water surface in the pool area and the center line of the conduit. Pressures were measured by means of piezometers.

Presentation of Data

6. Data showing the actual magnitude of pressures at each piezometer are presented in tabular form (tables 1-21) and also are plotted on various plates in terms of a pressure-drop coefficient. All data in the tables and on the plates are expressed in model dimensions. The pressure-drop coefficient for each piezometer is expressed as a function of the pressure drop from pool to the piezometer reading in question divided by the average velocity head in the conduit proper. Expression of the data in this form permits computation of the pressure gradient through a conduit entrance, regardless of head, velocity, or length of conduit.

PART II: RESULTS OF TESTS

Conduit Normal to Face of Dam

7. Initial tests were conducted with the conduit normal to the face of the dam and with the entrance shaped to the elliptical curve of

$$\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1$$

where D is the dimension of the conduit in the direction concerned. This entrance shape has been designated type A in this report and follows closely the alignment of a free jet through a narrow slit of infinite length. Pressure measurements for seven different head conditions are shown in table 1. Plate 1 shows the location of the piezometers. Plate 2 presents plots of the average pressure drop coefficients computed from pressure measurements along top center line and top corner and side center line of the entrance. These data indicate a gradually decreasing pressure gradient as flow enters the conduit proper. The lowest pressure was observed immediately upstream from the point of tangency with the conduit proper; pressures at the corner were slightly lower than those recorded along the center line of the entrance. However, this was to be expected, as the jet from a rectangular orifice is not rectangular in cross section due to the interference of flow at the corners. Since a rectangular-shaped entrance does not simulate the beveling of the corners of the jet issuing from a rectangular orifice, subnormal pressures will exist in these areas.

8. As previously stated, Professor Thomas proposed a method for designing a rectangular entrance in which the entrance was so aligned that the change in cross-sectional area had a direct relation to the change in hydraulic radius. The lengths of the side, top, and bottom curves were the same. Pressure measurements obtained on the rectangular-shaped intake proposed by Professor Thomas are listed in table 2. Plate 3 shows piezometer locations in the conduit designed by the Thomas entrance curves. A comparison of the pressure-drop coefficient data

obtained for this design with those obtained for the type A shape is shown on plate 2. These data indicate that a sudden pressure drop existed immediately after flow entered the conduit and that pressure conditions were considerably more critical than those obtaining with the type A entrance installed. Therefore, it was decided to confine all future tests to entrances of elliptical shape and to reduce the size of openings by decreasing the length of the semiminor axis.

9. Plate 4 shows a comparison of pressure-drop data with the semiminor axis of the elliptical entrance varied from D/3 to D/6 (types A, B, F, and G). Top center line and top corner piezometer data indicate a decrease in pressure, particularly in the upstream portion of the conduit entrance, as the D/3 ratio is decreased to D/6. Little difference existed in pressures for the D/4 and D/5 ratios. Pressure data on the side of the conduit also indicated a decrease in pressure as the semiminor axis was reduced below D/3 with the greatest decrease occurring as the axis was reduced below D/4. At the junction of the entrance and the conduit proper, pressure conditions appeared better with the type G entrance (D/6) than with the type A entrance (D/3). Actual pressure measurements are shown in tables 1, 3, 4, and 5. Piezometer locations in a longitudinal direction for each of the entrance types were as shown on plate 1.

10. Comparative data from tests wherein the semimajor axis of the entrance was varied are shown on plate 5 and tables 6, 7, and 8; piezometer locations for the type H approach are shown on plate 6. Also shown on these plates and in table 9 are the results of tests of the type C entrance wherein the axes of the side, top, and bottom curves were altered to provide the same area at the entrance as existed with type A. The data indicate the types A, B, and C entrances to be superior to those wherein the X-axis of the elliptical-shaped entrance was less than the dimension of the conduit in the particular direction concerned.

11. Comparative plots of pressure-drop coefficients and ratios of entrance area of conduit for various type entrances are shown on plate 7. The plots are based on top corner pressures which are the most critical of those measured. These data indicate that the type A entrance,

although the largest of those tested, resulted in the best pressure conditions at the conduit entrance. The type B entrance (D/4) was about the smallest (plate 4) that could be used without much change in pressure conditions.

12. Comparative data from tests wherein the semimajor and semiminor axes were varied 0.5 and 0.75 (types I and J) are shown on plate 8 and in tables 10 and 11. Piezometer locations for types I and J are shown on plates 9-10. Also shown on plate 8 is the type K entrance wherein the entrance was varied on all four sides in accordance with

$$\frac{X^2}{D^2} + \frac{Y^2}{(D/6)^2} = 1.$$

Pressures for the type K entrance are shown in table 12. These data substantiated the conclusion that entrances with the semimajor axis equal to the dimension of the conduit resulted in the most satisfactory pressure conditions.

13. As a result of analysis of the test data, the type L entrance (plate 11) was designed to provide the favorable pressure conditions observed in the upstream portion of the curve with type A,

$$\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1,$$

and in the downstream portion of the curve with type G,

$$\frac{X^2}{D^2} + \frac{Y^2}{(D/6)^2} = 1.$$

Best all-round performance was obtained with the type L design entrance. A comparison of the type L data with the type A and Thomas curves is shown on plate 2. Pressure measurements for the type L entrance are listed in table 13.

Conduit at Angle with Face of Dam

14. The type A entrance was used in initial tests to determine the

effect of varying the angle of the conduit axis with the upstream face of the dam. The axis of the conduit was placed alternately at angles of 10, 20, 30, and 40 degrees from normal to the face of the dam. For the most part the entrance shapes were constructed with the X and Y axes of the top and bottom curves parallel and perpendicular, respectively, to the axis of the conduit. The axes of the sides of the conduit entrance were normal to the face of the dam. For all tests the axis of the conduit proper was maintained in horizontal position. Piezometer locations are shown on plates 12-15; actual pressure measurements are presented in tables 14-17. Pressure-drop coefficient data for the center line and top corner piezometers are presented on plate 16. These data reveal that pressure conditions became more critical as the alignment of the conduit with the face of the dam departed from the normal position. The sharpest break in the pressure gradient occurred as the angle from the normal position exceeded 10 degrees.

15. Efforts to improve pressure conditions by revising the elliptical shape of the top curve and by skewing the Y axis parallel to the face of the dam were unsuccessful. Results of these tests are shown in tables 18 and 19 and on plate 17. Skewing the Y axis with the conduit 10 degrees from an alignment normal to the face of the dam had little effect; skewing the Y axis with the conduit 30 degrees from normal to the face of the dam, as shown on plate 18, made pressure conditions more critical.

Bulkhead Guides

16. The effect on pressures of slots cut into the entrance curves, or bulkhead guides, is another problem that arises in conduit design. No tests were conducted to determine the effect of slots in the entrance curves. The effect of bulkhead guides was studied on the type A entrance by installing 0.05-ft by 0.05-ft strips along the sides and bottom of the intake, 0.05 ft from the point of curvature of the entrance, as shown on plate 19. Comparison of the results presented in table 20 with the data shown in table 1 indicates that pressures were slightly lower without

bulkhead guides, although the difference is almost negligible. Piezometer locations are shown on plate 1.

Approach Channel Depth

17. A study also was made of the effect on pressure conditions of varying the depth of approach channel. The type A entrance curve was used, and the location of the horizontal floor of the approach channel was varied from 0.167 ft below the invert of the conduit (point of curvature of the bottom curve) to 1.75 ft below the invert. The entrance was normal to the face of the dam.

18. Pressures measured throughout the entrance and conduit for each approach depth are presented in table 21. The pressure-drop coefficients presented on plate 20 for the top center line, top corner, and side center line of the entrance indicate only slight differences as the approach depth altered. Pressures were slightly higher for the deeper approach depths than for the shallow approach depths. However, the pressure condition was reversed for pressures recorded on the bottom curve of the entrance, i.e., as the approach depth was decreased, pressures on the bottom entrance curve increased.

Discussion of Results

19. The test data presented herein should permit determination of expected pressures in critical areas of conduit entrances once a selected set of variables, such as head, length, alignment of conduit, and entrance size, is available. All data are based on a width-depth ratio of 0.567 which exists for a conduit 5 ft 8 in. wide by 10 ft high. Adaptation of these data to other size conduits leads to the assumption that the profiles of the jet through rectangular-shaped entrances for various ratios of width to depth are similar; the degree of accuracy of this assumption is unknown. Prototype tests have been and are being made to confirm or revise the data presented. For example, recent tests conducted at Pine

Flat Dam* (plate 21) indicate that pressure conditions at the conduit entrance are slightly more critical than indicated for the type A entrance; this is attributed to a greater turbulence loss in the prototype. The Pine Flat conduit is 5 ft wide by 9 ft high and the entrance curves are similar to the type A entrance.

20. Type L was the most ideal of the entrances tested in which rectangular conduits were flared in four directions. However, this entrance would be slightly larger and therefore more costly to build in the prototype than the type A entrance. For a gradual reduction in the pressure gradient through the conduit entrance, the entrance curves should be shaped to the elliptical curve of

$$\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1$$

where D is the dimension of the conduit proper in the horizontal or the vertical direction, as the case may be. While other entrance shapes with sharper degrees of curvature and smaller areas have been used successfully in certain instances, their satisfactory performance can usually be attributed to low head, back pressure created by a long conduit downstream, or an exit constriction. Where circumstances permit, departure from the elliptical curve defined above is justified if sufficient economies can be effected by the use of the smaller entrance. Also, slight variation of the conduit from an alignment normal to the face of the dam is permissible without alteration of the entrance curvature.

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* Waterways Experiment Station, Vibration, Pressure and Air-Demand Tests in Flood-Control Sluice, Pine Flat Dam, Kings River, California. Miscellaneous Paper No. 2-75 (February 1954).

Table 1

Pressure Data

Type A Entrance Curve

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.74	1.86	4.15	6.47	8.63	10.94	13.13
2	0.67	1.66	3.67	5.74	7.71	9.72	11.82
3	0.49	1.29	2.82	4.37	5.85	7.40	8.94
4	0.33	0.90	2.06	3.20	4.31	5.48	6.63
5	0.17	0.55	1.31	2.07	2.85	3.60	4.35
6	0.06	0.31	0.81	1.33	1.84	2.29	2.79
7	0.02	0.21	0.64	1.02	1.48	1.84	2.22
8	0.06	0.27	0.77	1.21	1.68	2.10	2.55
8-A	0.23	0.51	1.03	1.59	2.17	2.68	3.20
8-B	0.25	0.56	1.10	1.70	2.33	2.85	3.38
9	1.59	2.74	5.07	7.40	9.73	12.12	14.46
10	1.16	1.94	3.53	5.11	6.70	8.23	10.02
11	0.92	1.48	2.63	3.78	4.99	6.12	7.37
12	0.73	1.10	1.89	2.67	3.52	4.30	5.07
13	0.59	0.86	1.39	1.95	2.53	3.08	3.58
14	0.55	0.78	1.24	1.70	2.22	2.60	3.02
15	0.56	0.80	1.29	1.79	2.25	2.67	3.18
16	0.61	0.92	1.53	2.08	2.67	3.22	3.81
17	0.61	0.91	1.50	2.08	2.66	3.20	3.77
18	1.09	2.09	4.19	6.35	8.22	10.34	12.30
19	0.64	1.31	2.59	3.85	5.04	6.30	7.55
20	0.58	1.08	2.14	3.17	4.20	5.29	6.32
21	0.48	0.88	1.74	2.59	3.37	4.24	5.12
22	0.37	0.67	1.30	1.89	2.48	3.13	3.75
23	0.35	0.65	1.25	1.82	2.34	2.87	3.53
24	0.80	2.00	4.43	6.86	9.21	11.69	14.19
25	0.76	1.88	4.16	6.37	8.60	10.84	13.17
26	0.27	0.75	1.75	2.69	3.66	4.61	5.49
27	0.04	0.28	0.75	1.23	1.57	2.02	2.51
28	0.06	0.29	0.77	1.24	1.67	2.07	2.50
29	1.65	2.86	5.30	7.75	10.17	12.68	15.09
30	0.87	1.33	2.30	3.19	4.16	5.14	6.12
31	0.57	0.85	1.39	1.85	2.43	2.99	3.46
32	0.58	0.81	1.28	1.71	2.17	2.55	2.99
33	0.61	0.90	1.47	2.02	2.51	3.07	3.62
34	0.33	0.61	1.17	1.69	2.19	2.72	3.25
35	0.29	0.53	0.99	1.45	1.84	2.28	2.75
36	0.23	0.40	0.75	1.08	1.40	1.73	2.09
37	0.16	0.25	0.46	0.67	0.85	1.07	1.27
38	0.08	0.10	0.16	0.22	0.28	0.35	0.40
39	0.02	0.03	0.03	0.03	0.03	0.04	0.06

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 1.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1.$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 2

Pressure Data

Thomas Entrance Curve*

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.22	0.50	1.60	2.50	3.35	4.15	5.05
2	-0.26	-0.26	-0.46	-0.50	-0.71	-0.96	-1.16
3	-0.05	0.15	0.20	0.55	0.65	0.80	0.90
4	0.00	0.20	0.35	0.85	0.87	1.10	1.25
5	0.02	0.20	0.55	0.80	1.15	1.40	1.40
6	0.35	0.70	2.05	3.45	4.75	5.95	7.15
7	0.06	0.25	0.89	1.29	1.79	2.29	2.64
8	0.05	0.20	0.70	1.00	1.50	1.90	2.20
9	0.07	0.30	0.75	1.25	1.70	2.15	2.55
10	0.07	0.30	0.80	1.30	1.75	2.20	2.65
11	0.10	0.32	0.85	1.40	1.85	2.30	2.85
12	0.10	0.35	0.85	1.40	1.95	2.35	2.90
13	0.10	0.35	0.90	1.45	2.05	2.45	3.05
14	-0.05	0.03	0.28	0.43	0.70	0.93	0.88
15	-0.10	-0.10	0.05	0.10	0.15	0.15	0.25
16	0.90	1.60	3.45	5.05	7.15	8.80	10.35
17	0.42	0.75	1.45	2.15	2.75	3.65	4.15
18	0.40	0.70	1.35	2.00	2.60	3.60	3.65
19	0.40	0.68	1.30	1.90	2.45	3.55	3.55
20	0.37	0.65	1.20	1.85	2.30	2.80	3.30
21	0.65	0.95	1.55	2.15	2.75	3.25	3.75
22	0.65	0.95	1.60	2.25	2.80	3.35	3.95
23	0.65	0.92	1.55	2.20	2.75	3.30	3.85
24	0.37	0.65	1.20	1.80	2.00	2.85	3.35
25	0.35	0.60	1.35	1.60	2.05	2.55	2.95
26	0.63	0.83	1.43	2.03	2.68	3.23	3.68
27	0.58	0.81	1.31	1.76	2.26	2.71	2.86
28	0.55	0.75	1.20	1.60	2.05	2.35	2.70
29	0.55	0.80	1.25	1.75	1.70	2.65	3.00
30	0.55	0.80	1.30	1.85	2.25	2.70	3.10
31	0.58	0.82	1.35	1.95	2.40	2.85	3.30
32	0.10	0.35	0.90	1.55	2.05	2.55	3.05
33	0.10	0.35	0.90	1.40	2.00	2.50	3.25
34	0.35	0.55	1.15	1.60	2.15	2.60	3.10
35	0.30	0.50	0.95	1.40	1.85	2.30	2.70
36	0.22	0.35	0.70	1.00	1.35	1.70	2.00
37	0.10	0.15	0.20	0.40	0.50	0.60	0.75
38	0.07	0.05	0.10	0.20	0.25	0.30	0.40
39	0.00	0.00	0.00	0.00	0.00	0.00	0.05

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 3.

* "Design of Bellmouths for Entrances to Conduits of Circular, Square and Rectangular Cross Sections," dated July 1946, by Prof. H. A. Thomas of the Carnegie Institute of Technology.

Table 3

Pressure Data

Type B Entrance Curve

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.67	1.68	3.68	5.72	6.34	8.00	9.66
2	0.47	1.26	2.82	4.38	5.92	6.10	7.41
3	0.42	1.08	2.36	3.78	5.02	6.32	7.58
4	0.32	0.84	1.82	2.94	4.02	5.07	6.04
5	0.18	0.65	1.46	2.29	3.21	3.98	4.85
6	0.14	0.46	1.08	1.74	2.39	3.00	3.64
7	0.09	0.37	0.87	1.43	1.96	2.24	2.99
8	0.10	0.37	0.87	1.49	2.00	2.53	3.05
8-A	0.10	0.39	0.90	1.47	2.04	2.55	3.07
8-B	0.13	0.43	0.97	1.57	2.20	2.73	3.25
9	1.36	2.30	4.13	6.00	7.87	8.23	9.72
10	1.01	1.69	2.97	4.30	5.64	6.92	8.18
11	0.88	1.38	2.39	3.48	4.54	5.54	6.58
12	0.73	1.12	1.89	2.73	3.49	4.27	5.07
13	0.66	0.98	1.61	2.28	2.96	3.57	4.22
14	0.63	0.93	1.55	2.17	2.81	3.40	4.00
15	0.61	0.90	1.47	2.06	2.65	3.20	3.76
16	0.61	0.91	1.47	2.05	2.66	3.19	3.75
17	0.64	0.94	1.53	2.11	2.77	3.35	3.91
18	1.02	2.00	4.00	5.94	6.58	8.16	9.72
19	0.66	1.26	2.45	3.72	4.92	6.10	7.25
20	0.60	1.16	2.29	3.45	4.55	5.66	6.78
21	0.52	0.96	1.83	2.75	3.64	4.52	5.42
22	0.40	0.76	1.43	2.12	2.85	3.56	4.22
23	0.39	0.70	1.30	1.88	2.54	3.15	3.75
24	0.67	1.70	3.70	5.78	6.36	8.04	9.79
25	0.54	1.34	2.98	4.68	6.34	7.67	9.63
26	0.17	0.56	1.24	1.97	2.63	3.34	3.32
27	0.04	0.29	0.73	1.19	1.56	1.99	2.36
28	0.07	0.32	0.81	1.33	1.87	2.37	2.83
29	1.56	2.67	4.94	7.23	9.50	11.34	13.90
30	0.78	1.18	2.00	2.84	3.68	4.36	5.28
31	0.61	0.90	1.44	2.02	2.57	3.00	3.62
32	0.60	0.89	1.41	1.99	2.53	2.93	3.53
33	0.63	0.93	1.51	2.15	2.75	3.20	3.83
34	0.34	0.62	1.12	1.65	2.19	2.65	3.18
35	0.32	0.55	1.00	1.52	1.99	2.49	2.94
36	0.25	0.45	0.74	1.10	1.45	1.80	2.14
37	0.10	0.08	0.12	0.22	0.20	0.20	0.20
38	0.06	0.10	0.18	0.24	0.32	0.34	0.35
39	0.00	0.02	0.00	0.00	0.03	0.04	0.03

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 1.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/4)^2} = 1.$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 4

Pressure Data

Type F Entrance Curve

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.58	1.48	3.27	5.12	6.88	8.65	10.43
2	0.41	1.08	2.50	3.82	5.25	6.62	7.97
3	0.39	1.04	2.37	3.70	4.93	6.28	7.60
4	0.25	0.72	1.70	2.69	3.55	5.59	5.53
5	0.16	0.53	1.27	2.04	2.71	4.51	4.20
6	0.09	0.37	1.00	1.61	2.14	2.76	3.32
7	0.07	0.32	0.87	1.41	1.90	2.41	2.91
8	0.15	0.48	1.22	1.89	2.52	3.27	3.93
9	1.27	2.14	3.93	5.72	7.27	9.02	10.87
10	0.98	1.60	2.92	4.22	5.44	6.80	8.08
11	0.80	1.26	2.25	3.21	4.07	5.08	6.00
12	0.66	1.01	1.74	2.43	3.06	3.80	4.48
13	0.59	0.89	1.48	2.05	2.51	3.11	3.66
14	0.58	0.88	1.47	2.04	2.55	3.13	3.68
15	0.63	0.95	1.63	2.27	2.87	3.51	4.14
16	0.58	0.86	1.42	1.96	2.45	3.01	3.55
17	0.58	0.86	1.42	1.96	2.42	2.98	3.53
18	0.62	1.18	2.36	3.48	4.45	5.68	6.72
19	0.63	1.21	2.42	3.57	4.71	5.93	7.05
20	0.53	1.02	2.02	3.02	3.93	4.98	5.93
21	0.45	0.86	1.70	2.52	3.28	4.14	4.92
22	0.40	0.75	1.46	2.13	2.78	3.49	4.16
23	0.36	0.68	1.32	1.93	2.50	3.11	3.72
24	0.80	1.94	4.25	6.56	8.70	10.95	13.36
25	0.41	1.11	2.54	3.91	5.24	6.72	8.13
26	0.19	0.60	1.44	2.28	3.06	3.94	4.80
27	0.07	0.36	0.90	1.47	1.97	2.56	3.08
28	0.12	0.42	1.04	1.65	2.19	2.86	3.42
29	1.45	2.51	4.68	6.85	8.89	10.95	13.25
30	0.69	1.03	1.73	2.40	3.03	3.70	4.38
31	0.54	0.78	1.25	1.69	2.13	2.58	2.96
32	0.62	0.93	1.57	2.17	2.71	3.31	3.93
33	0.58	0.86	1.40	1.93	2.41	2.95	3.50
34	0.32	0.59	1.12	1.64	2.11	2.64	3.16
35	0.28	0.50	0.94	1.41	1.81	2.28	2.71
36	0.22	0.38	0.71	1.07	1.36	1.74	2.09
37	0.13	0.21	0.40	0.62	0.76	0.92	1.17
38	0.06	0.07	0.13	0.21	0.27	0.31	0.38
39	0.03	0.03	0.06	0.06	0.08	0.12	0.14

Note: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs
Piezometer locations shown on plate 1.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/5)^2} = 1.$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides

Table 5

Pressure Data

Type G Entrance Curve

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.39	1.07	2.36	3.62	4.88	6.21	7.52
2	0.24	0.77	1.85	2.85	3.87	4.87	5.90
3	0.34	0.88	2.03	3.11	4.23	5.31	6.48
4	0.25	0.69	1.59	2.47	3.33	4.22	5.11
5	0.17	0.50	1.21	1.90	2.59	3.26	3.96
6	0.13	0.43	1.06	1.66	2.28	2.86	3.46
7	0.13	0.42	1.01	1.58	2.17	2.71	3.31
8	0.14	0.45	1.07	1.67	2.29	2.87	3.48
9	1.02	1.66	2.89	4.16	5.47	6.64	7.99
10	0.90	1.46	2.69	3.68	4.83	5.93	6.89
11	0.79	1.22	2.26	2.99	3.89	4.78	5.69
12	0.70	1.06	1.88	2.45	3.17	3.88	4.60
13	0.63	0.94	1.62	2.13	2.75	3.33	3.95
14	0.62	0.91	1.52	2.05	2.63	3.19	3.79
15	0.63	0.93	1.52	2.10	2.71	3.29	3.90
16	0.64	0.94	1.55	2.13	2.74	3.32	3.93
17	0.63	0.91	1.46	2.04	2.61	3.14	3.74
18	0.48	0.85	1.61	2.35	3.17	3.80	4.47
19	0.63	1.15	2.25	3.32	4.40	5.43	6.56
20	0.54	1.00	1.95	2.87	3.81	4.70	5.68
21	0.50	0.90	1.73	2.57	3.39	4.20	5.08
22	0.42	0.75	1.43	2.08	2.77	3.41	4.12
23	0.40	0.70	1.34	1.95	2.59	3.18	3.85
24	0.63	1.52	3.33	5.10	6.60	8.61	10.40
25	0.16	0.56	1.41	2.24	2.88	3.72	4.59
26	0.17	0.53	1.27	2.00	2.74	3.45	4.24
27	0.12	0.40	0.99	1.54	2.15	2.70	3.34
28	0.13	0.42	1.01	1.59	2.17	2.72	3.33
29	1.34	2.28	4.23	6.15	7.77	9.91	11.97
30	0.70	1.04	1.78	2.46	3.21	3.87	4.61
31	0.63	0.90	1.47	2.05	2.61	3.16	3.78
32	0.63	0.93	1.55	2.14	2.78	3.35	4.00
33	0.61	0.89	1.44	1.98	2.86	3.02	3.59
34	0.34	0.61	1.13	1.65	2.17	2.65	3.22
35	0.30	0.51	0.96	1.38	1.84	2.27	2.75
36	0.23	0.38	0.71	1.05	1.38	1.74	2.09
38	0.08	0.08	0.15	0.20	0.27	0.32	0.41
39	0.03	0.03	0.05	0.07	0.09	0.11	0.16

Notes: Piezometer 37 was not read.
Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 1.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/6)^2} = 1$.

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 6

Pressure Data

Type D Entrance Curve

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.76	1.72	3.88	5.83	8.37	9.94	13.46
2	0.45	1.11	2.55	3.93	5.36	6.66	8.87
3	0.32	0.82	1.90	2.80	4.07	5.04	6.32
4	0.19	0.54	1.26	2.06	2.84	3.48	4.54
5	0.07	0.31	0.86	1.63	1.91	2.41	3.07
6	0.09	0.32	0.90	1.67	2.01	2.49	3.17
7	0.10	0.38	1.01	1.57	2.19	2.74	3.50
8	0.10	0.36	0.97	1.51	2.12	2.65	3.35
8-A	0.06	0.30	0.79	1.26	1.78	2.20	2.82
8-B	0.10	0.35	0.95	1.46	2.06	2.57	3.25
9	1.32	2.22	4.11	5.89	7.94	9.52	12.56
10	0.95	1.51	2.77	3.93	5.26	6.36	7.98
11	0.74	1.07	1.88	2.66	3.47	4.14	5.16
12	0.57	0.80	1.33	1.82	2.36	2.79	3.47
13	0.60	0.86	1.43	1.97	2.55	3.03	3.73
14	0.60	0.87	1.48	2.06	3.71	3.17	3.90
15	0.61	0.91	1.55	2.16	2.81	3.31	4.41
16	0.59	0.86	1.45	1.99	2.57	3.06	3.75
17	0.60	0.87	1.46	2.01	2.62	3.11	3.81
18	0.92	1.71	3.54	5.20	7.12	8.43	11.35
19	0.62	1.12	2.25	3.37	4.57	5.60	7.02
20	0.48	0.83	1.71	2.45	3.34	4.01	5.07
21	0.31	0.50	0.96	1.39	1.87	2.26	2.80
22	0.36	0.63	1.25	1.83	2.45	2.97	3.75
23	0.35	0.61	1.20	1.75	2.35	2.85	3.59
24	0.89	1.98	4.43	6.76	9.24	11.58	13.96
25	0.79	1.76	3.89	5.85	8.19	10.34	13.34
26	0.02	0.22	0.66	1.06	1.56	1.88	2.35
27	0.01	0.23	0.67	1.09	1.55	1.92	2.32
28	0.05	0.27	0.70	1.22	1.71	2.11	2.55
29	1.47	2.47	4.71	6.74	9.20	11.13	14.59
30	0.62	0.87	1.51	2.07	2.71	3.21	3.88
31	0.55	0.75	1.23	1.65	2.12	2.55	6.16
32	0.60	0.88	1.48	2.05	2.70	3.21	3.85
33	0.70	0.87	1.47	2.02	2.62	3.11	3.86
34	0.32	0.56	1.12	1.63	2.20	2.65	3.31
35	0.30	0.51	1.02	1.50	2.01	2.42	3.50
36	0.24	0.39	0.78	1.10	1.50	1.80	2.25
37	0.09	0.08	0.15	0.22	0.15	0.31	0.40
38	0.07	0.09	0.18	0.25	0.35	0.45	0.56
39	0.00	0.00	0.00	0.01	0.01	0.05	0.08

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 1.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1.$

D = 0.283 ft for all sides.

Table 7

Pressure Data

Type E Entrance Curve

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.75	1.78	3.90	6.08	8.03	10.06	12.18
2	0.24	0.80	1.76	2.76	3.67	4.66	5.63
3	0.24	0.76	1.74	2.57	3.60	4.46	5.42
4	0.09	0.44	1.09	1.54	2.08	2.70	3.22
5	0.10	0.42	1.02	1.46	1.96	2.52	3.04
6	0.10	0.44	1.02	1.48	1.98	2.56	3.10
7	0.10	0.42	0.98	1.41	1.94	2.48	2.98
8	0.10	0.41	0.96	1.38	1.89	2.41	2.92
8-A	0.08	0.40	1.04	1.50	2.00	2.48	3.00
8-B	0.06	0.38	0.98	1.44	1.94	2.38	2.88
9	0.87	1.42	2.40	3.34	4.34	5.44	6.42
10	0.80	1.30	2.20	3.17	4.14	5.10	6.04
11	0.61	0.96	1.60	2.13	2.73	3.44	4.06
12	0.60	0.92	1.51	2.04	2.60	3.22	3.72
13	0.60	0.88	1.46	2.00	2.54	3.12	3.62
14	0.60	0.88	1.44	1.96	2.45	3.02	3.56
15	0.58	0.87	1.44	1.84	2.32	2.88	3.34
16	0.60	0.92	1.50	1.94	2.42	3.02	3.52
17	0.60	0.92	1.50	1.94	2.42	3.02	3.52
18	0.82	1.64	3.27	4.92	6.40	7.86	9.47
19	0.52	0.94	1.82	2.70	3.51	4.36	5.21
20	0.40	0.78	1.50	2.15	2.78	3.52	4.25
21	0.38	0.72	1.39	2.06	2.72	3.38	4.08
22	0.36	0.68	1.32	1.75	2.25	2.82	3.35
23	0.34	0.66	1.24	1.72	2.18	2.66	3.18
24	0.82	1.94	4.22	6.42	8.66	10.89	13.13
25	0.44	1.14	2.56	4.06	5.50	6.83	8.12
26	0.01	0.24	0.65	0.92	1.30	1.60	1.94
27	0.02	0.31	0.80	1.16	1.63	2.04	2.45
28	0.04	0.34	0.82	1.28	1.78	2.24	2.72
29	1.23	2.08	3.90	5.52	7.20	8.88	10.64
30	0.53	0.75	1.22	1.68	2.06	2.46	2.90
31	0.51	0.72	1.19	1.52	1.88	2.21	2.55
32	0.52	0.74	1.18	1.58	1.92	2.26	2.62
33	0.55	0.85	1.34	1.75	2.25	2.65	3.40
34	0.32	0.60	1.16	1.70	2.25	2.71	3.21
35	0.28	0.60	1.02	1.62	2.12	2.51	2.98
36	0.22	0.48	0.90	1.12	1.58	1.85	2.18
37	0.08	0.10	0.12	0.12	0.18	0.20	0.20
38	0.05	0.12	0.16	0.26	0.32	0.42	0.52
39	0.00	0.00	0.00	0.02	0.02	0.05	0.07

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 1.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/4)^2} = 1.$

D = 0.283 ft for all sides.

Table 8

Pressure Data

Type H Entrance Curve

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.40	0.95	2.17	3.35	4.50	5.60	6.40
2	0.02	0.20	0.62	0.99	1.37	1.72	2.02
3	0.23	0.60	1.40	2.23	3.08	3.81	4.30
4	0.16	0.52	1.11	1.81	2.49	3.06	3.12
5	0.12	0.30	0.93	1.50	2.08	2.52	2.92
6	0.12	0.42	0.98	1.55	2.15	2.68	3.03
7	0.12	0.42	0.99	1.60	2.20	2.72	3.11
8	0.12	0.42	1.02	1.58	2.18	2.71	3.10
8-A	0.12	0.42	1.01	1.58	2.18	2.71	3.10
8-B	0.12	0.41	1.00	1.55	2.18	2.69	3.05
9	0.73	1.08	1.88	2.55	3.25	3.88	4.40
10	0.73	1.13	1.94	2.73	3.53	4.26	4.76
11	0.67	1.01	1.72	2.37	3.07	3.65	4.07
12	0.59	0.86	1.39	1.91	2.46	2.88	3.22
13	0.62	0.90	1.52	2.10	2.68	3.20	3.55
14	0.63	0.92	1.55	2.13	2.70	3.28	3.65
15	0.63	0.95	1.57	2.15	2.75	3.35	3.75
16	0.63	0.93	1.52	2.10	2.70	3.25	3.60
17	0.63	0.94	1.53	2.13	2.72	3.30	3.67
18	0.37	0.65	1.25	1.75	2.25	2.52	3.18
19	0.47	0.88	1.70	2.50	3.35	4.10	4.57
20	0.43	0.80	1.58	1.25	2.95	3.60	4.08
21	0.38	0.70	1.35	1.95	2.65	3.18	3.53
22	0.37	0.67	1.27	1.85	2.45	2.98	3.37
23	0.37	0.67	1.28	1.88	2.50	3.05	3.40
24	0.72	1.73	3.64	5.43	7.38	9.28	10.40
25	0.08	0.35	0.77	1.10	1.42	1.95	3.27
26	0.05	0.26	0.64	0.99	1.39	1.71	1.89
27	0.09	0.35	0.87	1.35	0.85	2.30	2.63
28	0.12	0.41	1.00	1.58	2.10	3.68	3.05
29	1.19	2.05	3.75	5.55	7.25	9.00	10.00
30	0.53	0.71	1.08	1.44	1.81	2.09	2.32
31	0.59	0.88	1.41	1.95	2.42	2.97	3.32
32	0.62	0.93	1.53	2.13	2.75	3.32	3.70
33	0.61	0.90	1.43	1.93	2.45	2.97	3.25
34	0.35	0.62	1.13	1.65	2.15	2.65	2.98
35	0.29	0.51	0.95	1.37	1.85	2.23	2.53
36	0.23	0.38	0.74	1.06	1.40	1.65	1.93
38	0.08	0.08	0.14	0.19	0.25	0.33	0.33
39	0.03	0.03	0.05	0.05	0.07	0.10	0.12

Notes: Piezometer No. 37 was not read.
Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 6.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/6)^2} = 1$.

D = 0.283 ft for top and bottom.
D = 0.283 ft for sides.

Table 9

Pressure Data

Type C Entrance Curve

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.71	1.88	3.95	6.01	8.13	10.24	12.20
2	0.58	1.50	3.24	4.88	6.84	8.43	10.06
3	0.54	1.46	2.82	4.58	6.10	7.59	9.14
4	0.56	1.33	2.54	3.84	5.40	6.72	7.87
5	0.35	0.95	2.08	2.88	4.05	4.93	5.90
6	0.20	0.69	1.42	2.19	3.10	3.85	4.56
7	0.17	0.55	1.11	1.75	2.50	3.07	3.67
8	0.13	0.47	1.01	1.60	2.27	2.83	3.31
8-A	0.13	0.40	0.90	1.43	2.05	2.51	3.00
8-B	0.10	0.40	0.93	1.50	2.11	2.57	3.07
9	1.48	2.68	4.76	6.95	9.21	11.32	13.33
10	1.13	2.10	3.52	5.11	7.38	8.33	9.57
11	1.02	1.78	3.10	4.48	6.02	7.30	8.43
12	0.85	1.46	2.42	3.45	4.59	5.57	6.45
13	0.71	1.18	1.92	2.72	3.60	4.37	5.09
14	0.65	1.01	1.57	2.23	2.91	3.47	3.97
15	0.63	0.99	1.55	2.17	2.84	3.40	3.97
16	0.60	0.90	1.35	1.95	2.51	3.00	3.50
17	0.63	0.97	1.50	2.13	2.76	3.27	3.85
18	1.10	2.32	4.35	6.40	8.57	10.82	12.81
19	0.80	1.66	3.32	4.62	6.22	7.67	8.94
20	0.70	1.42	2.70	3.90	5.20	6.58	7.80
21	0.59	1.18	2.12	3.18	4.40	5.38	6.30
22	0.42	0.82	1.45	2.16	2.95	3.60	4.22
23	0.35	0.66	1.10	1.80	2.45	2.96	3.48
24	0.78	2.08	4.21	6.44	8.95	11.15	13.13
25	0.67	1.74	3.59	5.54	7.49	9.44	11.11
26	0.41	1.02	1.72	3.45	4.52	5.75	7.13
27	0.25	0.64	1.26	2.00	2.82	3.50	4.19
28	0.10	0.47	0.95	1.51	2.20	2.73	3.23
29	1.59	2.88	5.17	7.43	10.23	11.82	14.55
30	0.98	1.68	2.88	4.13	5.14	6.74	7.89
31	0.73	1.11	1.74	2.42	3.24	3.88	4.56
32	0.61	0.97	1.47	2.05	2.70	3.23	3.75
33	0.67	1.13	1.57	2.25	2.93	3.45	3.80
34	0.35	0.61	1.10	1.66	2.22	2.71	3.15
35	0.34	0.58	1.01	1.48	2.06	2.48	2.86
36	0.22	0.45	0.75	1.10	1.50	1.84	2.06
37	0.08	0.05	0.11	0.20	0.20	0.21	0.28
38	0.08	0.10	0.18	0.25	0.35	0.45	0.45
39	0.00	0.00	0.01	0.01	0.02	0.02	0.05

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 1.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(0.122)^2} = 1.$

D = 0.500 ft for all sides.

Area of the conduit at the dam face equal to area for entrance whose curves are:

$$\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1.$$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 10

Pressure Data

Type I Entrance Curves

Piez Number	H = 1.25 ft Q = 1.10 cfs	H = 2.50 ft Q = 1.55 cfs	H = 5.00 ft Q = 2.25 cfs	H = 7.50 ft Q = 2.72 cfs	H = 10.00 ft Q = 3.15 cfs	H = 12.50 ft Q = 3.55 cfs	H = 15.00 ft Q = 3.87 cfs
				Top Center Line			
1	0.54	1.35	3.03	4.67	6.32	7.87	9.57
2	0.24	0.69	1.63	2.55	3.45	4.30	5.35
3	0.13	0.49	1.15	1.82	2.50	3.07	3.77
4	0.11	0.36	0.91	1.58	1.93	2.46	3.01
5	0.08	0.32	0.84	1.30	1.83	2.31	2.83
6	0.02	0.19	0.52	0.84	1.10	1.41	1.68
7	-0.03	0.09	0.31	0.51	0.70	0.88	1.10
8	-0.02	0.14	0.40	0.61	0.85	1.06	1.25
9	0.03	0.18	0.56	0.94	1.28	1.55	1.87
10	0.05	0.25	0.67	1.10	1.52	1.86	2.29
11	0.06	0.27	0.73	1.16	1.61	2.04	2.47
12	0.11	0.34	0.84	1.32	1.83	2.32	2.81
13	0.10	0.35	0.88	1.37	1.90	2.40	2.90
14	0.12	0.37	0.92	1.44	2.00	2.51	3.05
15	0.12	0.38	0.94	1.47	2.05	2.53	3.09
16	0.13	0.40	0.99	1.57	2.14	2.70	3.34
17	0.13	0.42	1.01	1.60	2.17	2.73	3.36
18	0.13	0.42	1.00	1.56	2.17	2.68	3.28
				Top Corner			
19	0.79	1.87	4.07	6.47	8.42	10.32	12.52
20	0.37	0.97	2.15	3.35	4.48	5.73	6.60
21	-0.10	-0.10	-0.05	0.04	0.17	0.22	0.33
22	-0.29	-0.35	-0.58	-0.90	-1.17	-1.44	-1.82
23	-----	-----	-----	-----	-----	-----	-----
24	-0.21	-0.33	-0.63	-0.96	-1.26	-1.61	-2.03
25	-0.24	-0.37	-0.72	-1.09	-1.55	-1.86	-2.21
26	-0.07	0.04	0.18	0.37	0.45	0.65	0.80
27	-0.03	0.08	0.34	0.60	0.85	1.07	1.35
28	-0.02	0.11	0.36	0.61	0.88	1.04	1.28
29	0.03	0.23	0.53	0.88	1.23	1.55	1.82
30	0.07	0.28	0.74	1.20	1.67	2.11	2.55
31	0.08	0.35	0.85	1.35	1.89	2.38	2.90
32	0.10	0.36	0.89	1.42	1.95	2.48	3.02
33	0.12	0.38	0.94	1.52	2.08	2.62	3.20
34	-----	-----	-----	-----	-----	-----	-----
35	0.15	0.45	1.10	1.62	2.30	2.95	3.58
36	0.14	0.44	1.05	1.64	2.28	2.87	3.48
				Side Center Line			
37	0.61	1.19	2.12	3.12	4.15	5.12	6.10
38	0.19	0.30	0.41	0.50	0.65	0.75	0.80
39	0.24	0.42	0.68	0.92	1.02	1.37	1.60
40	0.40	0.74	1.50	2.23	2.95	3.62	4.35
41	0.43	0.81	1.58	2.28	3.10	3.87	4.59
42	0.41	0.72	1.41	2.10	2.77	3.46	4.21
43	0.40	0.71	1.37	2.05	2.68	3.33	4.00
44	0.39	0.70	1.32	1.90	2.53	3.17	3.80
45	0.38	0.68	1.28	1.89	2.50	3.11	3.73
46	0.38	0.65	1.25	1.88	2.47	3.06	3.67
47	0.37	0.65	1.24	1.83	2.45	3.03	3.60
48	0.37	0.65	1.24	1.83	2.43	3.01	3.58
49	0.37	0.66	1.25	1.85	2.48	3.04	3.65
50	0.37	0.65	1.24	1.81	2.41	2.99	3.60
51	0.37	0.65	1.24	1.80	2.39	3.00	3.60
52	0.37	0.64	1.20	1.77	2.31	2.93	3.50
53	0.37	0.64	1.20	1.76	2.28	2.85	3.45
54	-----	-----	-----	-----	-----	-----	-----
55	0.33	0.61	1.10	1.61	2.15	2.68	3.22
56	0.29	0.49	0.91	1.32	1.78	2.20	2.61
57	0.21	0.34	0.63	0.92	1.23	1.53	1.82
58	0.15	0.22	0.37	0.53	0.73	0.85	1.02
59	0.09	0.10	0.13	0.20	0.25	0.30	0.35
60	0.02	0.00	-0.01	-0.03	-0.05	-0.07	-0.08

Notes: Pressures in feet of water.
H = Head in feet of water above conduit center line.
Q = Discharge in cfs.
Piezometer locations shown on plate 9.
Equation for entrance curves: $\frac{X^2}{(0.5D)^2} + \frac{Y^2}{(0.5D/3)^2} = 1$.
D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 11

Pressure Data

Type J Entrance Curves

Piez Number	H = 1.25 ft Q = 1.10 cfs	H = 2.50 ft Q = 1.55 cfs	H = 5.00 ft Q = 2.25 cfs	H = 7.50 ft Q = 2.72 cfs	H = 10.00 ft Q = 3.15 cfs	H = 12.50 ft Q = 3.55 cfs	H = 15.00 ft Q = 3.87 cfs
				Top Center Line			
1	0.73	1.78	3.90	5.98	8.11	10.23	12.18
2	0.49	1.27	2.77	4.28	5.79	7.25	8.72
3	0.42	1.10	2.44	3.77	5.11	6.42	7.71
4	0.38	0.97	2.15	3.32	4.55	5.73	6.91
5	0.32	0.84	1.88	2.93	4.01	5.02	6.03
6	0.24	0.71	1.64	2.58	3.51	4.42	5.35
7	0.18	0.58	1.37	2.18	2.97	3.75	4.57
8	0.13	0.43	1.09	1.71	2.18	2.83	3.43
9	0.04	0.39	0.78	1.24	1.79	2.27	2.76
10	0.04	0.26	0.76	1.21	1.67	2.14	2.61
11	0.03	0.24	0.66	1.08	1.55	2.00	2.43
12	0.04	0.24	0.68	1.08	1.53	1.94	2.36
13	0.05	0.25	0.70	1.12	1.56	1.97	2.40
14	0.07	0.30	0.79	1.27	1.68	2.16	2.62
15	0.08	0.33	0.87	1.36	1.89	2.36	2.88
16	0.10	0.38	0.92	1.48	2.02	2.56	3.10
17	0.10	0.37	0.90	1.42	1.93	2.46	2.98
18	0.07	0.30	0.76	1.19	1.62	2.05	2.45
				Top Corner			
19	0.80	1.96	4.28	6.55	8.84	11.15	13.37
20	0.50	1.26	2.82	4.30	5.85	7.44	8.90
21	0.38	1.01	2.26	3.54	4.78	5.99	7.21
22	0.26	0.76	1.79	2.80	2.69	3.30	3.97
23	0.18	0.46	1.12	1.81	2.46	3.14	3.78
24	0.11	0.39	1.02	1.68	2.28	2.92	3.58
25	0.05	0.30	0.79	1.29	1.80	2.26	2.77
26	0.02	0.21	0.66	1.04	1.44	1.86	2.28
27	-0.01	0.16	0.50	0.82	1.20	1.51	1.86
28	-0.02	0.12	0.42	0.70	0.97	1.26	1.54
29	0.01	0.17	0.53	0.85	1.17	1.52	1.91
30	0.03	0.18	0.57	0.96	1.32	1.70	2.09
31	0.02	0.20	0.57	0.96	1.28	1.66	2.03
32	0.07	0.31	0.80	1.29	1.73	2.25	2.71
33	0.11	0.35	0.88	1.38	1.87	2.37	2.88
34	0.11	0.34	0.86	1.32	1.84	2.30	2.76
35	0.10	0.33	0.82	1.29	1.77	2.20	2.68
36	0.07	0.29	0.77	1.23	1.66	2.16	2.57
				Side Center Line			
37	0.93	1.77	3.47	5.16	6.88	8.52	10.33
38	0.63	1.12	2.07	3.03	4.00	4.95	5.89
39	0.63	1.17	2.26	3.38	4.45	5.51	6.57
40	0.53	1.00	1.98	2.96	4.00	4.87	5.83
41	0.49	0.92	1.83	2.71	3.60	4.50	5.37
42	0.45	0.85	1.64	2.45	3.20	4.02	4.83
43	0.44	0.80	1.55	2.30	3.03	3.78	4.53
44	0.41	0.74	1.45	2.14	2.81	3.52	4.23
45	0.39	0.71	1.37	2.04	2.66	3.32	3.98
46	0.37	0.69	1.31	1.93	2.55	3.19	3.82
47	0.36	0.66	1.26	1.84	2.43	3.02	3.60
48	0.35	0.63	1.23	1.81	2.36	2.95	3.50
49	0.35	0.62	1.20	1.76	2.31	2.87	3.42
50	0.34	0.60	1.17	1.69	2.23	2.79	3.30
51	0.34	0.60	1.15	1.68	2.20	2.76	3.28
52	0.35	0.62	1.21	1.76	2.30	2.89	3.43
53	0.34	0.61	1.19	1.73	2.25	2.81	3.35
54	0.33	0.59	1.11	1.60	2.07	2.57	3.08
55	0.33	0.60	1.12	1.63	2.15	2.65	3.19
56	0.29	0.51	0.94	1.38	1.80	2.22	2.68
57	0.21	0.36	0.65	0.95	1.25	1.52	1.82
58	0.15	0.22	0.37	0.53	0.68	0.82	0.98
59	0.09	0.09	0.13	0.16	0.19	0.23	0.28
60	0.02	0.01	-0.02	-0.08	-0.07	-0.10	-0.12

Notes: Pressures in feet of water.
H = Head in feet of water above conduit center line.
Q = Discharge in cfs.
Piezometer locations shown on plate 10.
Equation for entrance curves: $\frac{X^2}{(0.75D)^2} + \frac{Y^2}{(0.75D/3)^2} = 1$.
D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 12

Pressure Data

Type K Entrance Curves

Piez Number	H = 1.25 ft Q = 1.08 cfs	H = 2.50 ft Q = 1.57 cfs	H = 5.00 ft Q = 2.19 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.17 cfs	H = 12.50 ft Q = 3.57 cfs	H = 15.00 ft Q = 3.95 cfs
			Top Center Line				
1	0.58	1.43	3.16	4.85	6.54	7.89	9.94
2	0.34	0.96	2.21	3.39	4.58	5.63	6.89
3	0.48	1.22	2.67	4.04	5.55	6.94	8.50
4	0.51	1.25	2.70	4.16	5.66	7.03	8.64
5	0.50	1.24	2.64	4.07	5.55	6.94	8.47
6	0.46	1.15	2.47	3.82	5.19	6.44	7.86
7	0.45	1.11	2.40	3.70	5.05	6.28	7.67
8	0.42	1.05	2.28	3.53	4.83	6.05	7.35
9	0.38	0.96	2.12	3.27	4.45	5.57	6.78
10	0.35	0.89	1.97	3.06	4.16	5.19	6.34
11	0.31	0.83	1.81	2.83	3.84	4.83	5.91
12	0.24	0.78	1.54	2.41	3.29	4.16	5.06
13	0.19	0.57	1.32	2.07	2.82	3.54	4.30
14	0.17	0.50	1.15	1.84	2.50	3.15	3.84
15	0.12	0.42	1.00	1.59	2.17	2.74	3.34
16	0.10	0.38	0.92	1.45	2.00	2.54	3.08
17	0.05	0.27	0.70	1.14	1.57	1.99	2.42
18	0.05	0.25	0.69	1.12	1.54	1.92	2.35
			Top Corner				
19	0.62	1.54	3.47	5.30	7.12	8.74	10.77
20	0.51	1.26	2.76	3.29	5.73	7.13	8.76
21	0.37	0.99	2.17	3.37	4.50	5.72	6.92
22	0.48	1.16	2.56	3.98	5.36	6.68	8.18
23	0.41	1.04	2.27	3.52	4.79	5.99	7.31
24	0.40	1.00	2.17	3.37	4.54	5.69	6.89
25	0.39	0.98	2.17	3.37	4.56	5.72	6.95
26	0.37	0.95	2.09	3.25	4.40	5.52	6.67
27	0.34	0.87	1.93	3.03	4.12	5.15	6.30
28	0.29	0.77	1.71	2.63	3.56	4.43	5.49
29	0.25	0.66	1.51	2.34	3.19	4.01	4.84
30	0.21	0.58	1.34	2.13	2.89	3.66	4.44
31	0.20	0.52	1.22	1.90	2.62	3.07	3.99
32	0.14	0.42	0.99	1.57	2.12	2.67	3.22
33	0.06	0.25	0.64	1.02	1.39	1.77	2.15
34	0.08	0.32	0.79	1.24	1.72	2.17	2.59
35	0.08	0.30	0.75	1.17	1.64	2.09	2.52
36	0.02	0.17	0.54	0.77	0.59	1.24	1.52
			Side Center Line				
37	1.09	2.19	4.37	6.50	8.67	10.39	12.92
38	0.84	1.57	3.07	4.57	6.10	7.55	9.19
39	0.73	1.43	2.83	4.21	5.60	5.47	6.55
40	0.79	1.51	2.94	4.39	5.84	7.27	8.82
41	0.74	1.35	2.73	4.07	5.42	6.75	8.20
42	0.69	1.30	2.52	3.77	5.04	6.25	7.62
43	0.60	1.13	2.20	3.29	4.39	5.44	6.60
44	0.53	0.97	1.89	2.80	3.75	4.64	5.67
45	0.47	0.87	1.67	2.47	3.29	4.07	4.94
46	0.45	0.80	1.52	2.29	3.02	3.75	4.57
47	0.41	0.74	1.41	2.10	2.79	3.39	4.17
48	0.38	0.69	1.28	1.85	2.52	3.10	3.74
49	0.34	0.61	1.15	1.69	2.24	2.72	3.29
50	0.33	0.58	1.10	1.60	2.12	2.60	3.17
51	0.32	0.56	1.05	1.55	2.05	2.52	3.09
52	0.31	0.54	1.00	1.49	1.95	2.37	2.90
53	0.30	0.52	0.97	1.42	1.84	2.24	2.72
54	0.31	0.53	0.98	1.41	1.85	2.24	2.69
55	0.34	0.59	1.09	1.60	2.10	2.59	3.12
56	0.34	0.52	0.94	1.35	1.80	2.18	2.59
57	0.22	0.36	0.69	1.02	1.30	1.62	1.97
58	0.14	0.22	0.40	0.57	0.75	0.92	1.10
59	0.06	0.07	0.09	0.13	0.15	0.20	0.24
60	0.00	-0.02	-0.03	-0.05	-0.06	-0.08	-0.10

Notes: Pressures in feet of water.
H = Head in feet of water above conduit center line.
Q = Discharge in cfs.

Equation for top, bottom, and side entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/6)^2} = 1$

D = 0.500 ft.

Table 13

Pressure Data

Type L Entrance Curves

Piez Number	H = 1.25 ft Q = 1.08 cfs	H = 2.50 ft Q = 1.58 cfs	H = 5.00 ft Q = 2.24 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.18 cfs	H = 12.50 ft Q = 3.57 cfs	H = 15.00 ft Q = 3.95 cfs
				Top Center Line			
1	0.78	1.93	4.24	6.56	8.88	11.13	13.47
2	0.62	1.55	3.41	5.24	7.07	8.90	10.65
3	0.56	1.40	3.10	4.79	6.45	8.13	9.85
4	0.51	1.28	2.83	4.40	5.93	7.49	9.03
5	0.44	1.14	2.53	3.92	5.28	6.66	8.29
6	0.39	1.01	2.24	3.48	4.69	5.92	7.12
7	0.34	0.90	2.02	3.14	4.26	5.41	6.54
8	0.26	0.72	1.64	2.57	3.49	4.44	5.37
9	0.20	0.57	1.36	2.17	2.91	3.72	4.51
10	0.16	0.49	1.19	1.88	2.57	3.28	4.01
11	0.14	0.45	1.11	1.74	2.39	3.07	3.74
12	0.15	0.46	1.15	1.82	2.50	3.25	3.95
13	0.15	0.46	1.13	1.79	2.47	3.12	3.78
14	0.13	0.43	1.08	1.73	2.36	2.98	3.62
15	0.10	0.39	0.99	1.58	2.20	2.75	3.36
16	0.11	0.41	1.04	1.65	2.26	2.84	3.45
17	0.10	0.39	1.00	1.58	2.17	2.73	3.32
18	0.10	0.38	0.97	1.55	2.12	2.65	3.22
19	0.10	0.40	1.02	1.61	2.22	2.77	3.35
20	0.10	0.40	1.01	1.60	2.19	2.79	3.32
21	0.11	0.41	1.03	1.63	2.22	2.75	3.38
22	0.12	0.43	1.04	1.64	2.22	2.80	3.38
				Top Corner			
23	0.81	2.04	4.46	6.91	9.31	11.73	14.42
24	0.67	1.67	3.65	5.64	7.63	9.58	11.01
25	0.51	1.31	2.93	4.53	6.09	7.67	9.28
26	0.43	1.11	2.51	3.90	5.26	6.70	8.07
27	0.36	0.95	2.16	3.38	4.59	5.82	7.01
28	0.30	0.84	1.91	2.95	4.00	5.04	6.14
29	0.23	0.67	1.56	2.44	3.30	4.18	5.06
30	0.18	0.51	1.22	1.96	2.66	3.36	4.12
31	0.12	0.42	1.07	1.70	2.36	2.98	3.65
32	0.10	0.38	1.04	1.65	2.28	2.89	3.55
33	0.10	0.41	1.04	1.67	2.30	2.88	3.52
34	0.11	0.41	1.04	1.65	2.27	2.86	3.49
35	0.14	0.43	1.08	1.71	2.35	2.97	3.60
36	0.13	0.42	1.06	1.69	2.34	2.96	3.59
37	0.11	0.40	1.01	1.59	2.21	2.79	3.38
38	0.09	0.38	1.00	1.58	2.19	2.77	3.37
39	0.10	0.38	0.97	1.54	2.13	2.68	3.27
40	0.09	0.37	0.96	1.50	2.08	2.62	3.19
41	0.10	0.38	0.97	1.54	2.11	2.66	3.24
42	0.11	0.40	1.00	1.59	2.16	2.74	3.32
43	0.11	0.39	0.99	1.58	2.15	2.70	3.25
44	0.10	0.38	0.97	1.53	2.09	2.62	3.15
				Side Center Line			
45	0.96	1.92	3.84	5.70	7.50	9.40	11.22
46	0.82	1.62	3.22	4.78	6.32	7.92	9.42
47	0.76	1.49	2.95	4.39	5.79	7.25	8.64
48	0.70	1.35	2.68	4.02	5.29	6.60	7.89
49	0.64	1.24	2.47	3.67	4.87	6.04	7.29
50	0.59	1.13	2.20	3.29	4.36	5.41	6.52
51	0.54	1.03	2.02	3.04	4.03	5.03	6.05
52	0.48	0.92	1.77	2.64	3.50	4.33	5.22
53	0.45	0.85	1.64	2.43	3.20	3.95	4.76
54	0.43	0.79	1.54	2.27	3.01	3.73	4.49
55	0.38	0.74	1.49	2.24	2.97	3.71	4.47
56	0.36	0.68	1.31	1.96	2.61	3.21	3.84
57	0.35	0.67	1.37	2.05	2.73	3.40	4.11
58	0.36	0.65	1.22	1.81	2.38	2.92	3.52
59	0.36	0.67	1.33	1.97	2.61	3.22	3.89
60	0.36	0.67	1.35	2.00	2.65	3.30	3.71
61	0.35	0.66	1.31	1.95	2.55	3.16	3.80
62	0.35	0.65	1.28	1.88	2.46	3.03	3.64
63	0.34	0.61	1.15	1.69	2.21	2.70	3.22
64	0.30	0.48	0.95	1.39	1.82	2.26	2.70
65	0.23	0.37	0.70	1.03	1.34	1.65	1.97
66	0.15	0.22	0.41	0.60	0.78	0.95	1.14
67	0.07	0.09	0.15	0.21	0.29	0.35	0.42
68	0.01	0.01	0.01	0.03	0.04	0.05	0.06

Notes: Pressures in feet of water.
H = Head in feet of water above conduit center line.
Q = Discharge in cfs.
Piezometer locations shown on plate 11.
Equations for top, bottom, and side curves are: $\frac{X^2}{D^2} + \frac{Y^2}{(0.32D)^2} = 1$ and $\frac{X^2}{D^2} + \frac{Y^2}{(0.16D)^2} = 1.$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 14

Pressure Data

Conduit with Axis 10 Degrees from Normal to Face of Dam

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.65	1.75	3.93	6.05	8.20	10.30	12.55
2	0.44	1.24	2.77	4.30	5.88	7.38	8.85
3	0.23	0.69	1.65	2.62	3.59	4.49	5.48
4	0.11	0.44	1.09	1.74	2.35	3.00	3.61
5	0.01	0.23	0.66	1.06	1.46	1.92	2.26
6	0.01	0.19	0.57	0.91	1.24	1.67	1.97
7	0.01	0.19	0.56	0.92	1.24	1.62	1.94
8	0.07	0.28	0.74	1.18	1.60	2.03	2.52
9	1.59	2.78	5.15	7.49	9.86	12.15	14.56
10	1.33	2.28	4.22	6.05	8.00	9.83	11.90
11	1.14	1.91	3.49	5.04	6.67	8.32	9.89
12	0.95	1.52	2.79	3.97	5.11	6.42	7.62
13	0.76	1.16	2.01	2.93	3.74	4.54	5.46
14	0.67	1.01	1.71	2.31	2.91	3.78	4.28
15	0.68	1.02	1.70	2.38	3.05	3.78	4.40
16	0.67	0.99	1.65	2.30	2.92	3.53	4.23
17	0.63	0.94	1.52	2.10	2.63	3.28	3.80
18	0.97	1.95	3.88	5.85	7.63	9.75	11.65
19	0.66	1.27	2.54	3.75	4.91	6.17	7.37
20	0.54	1.00	1.98	2.94	3.85	4.76	5.69
21	0.48	0.89	1.75	2.58	3.40	4.23	5.03
22	0.42	0.78	1.54	2.25	3.00	3.67	4.45
23	0.40	0.70	1.33	1.95	2.57	3.22	3.80
24	0.78	1.98	4.38	6.77	9.18	11.52	13.89
25	0.52	1.38	3.10	4.85	6.67	8.25	9.98
26	-0.03	0.11	0.41	0.73	0.98	1.28	1.61
27	0.01	0.14	0.46	0.76	1.04	1.39	1.69
28	0.07	0.28	0.72	1.13	1.55	1.98	2.40
29	1.64	2.88	5.34	7.81	10.25	12.68	15.15
30	1.09	1.83	3.31	4.74	6.13	7.67	9.09
31	0.74	1.16	1.99	2.79	3.49	4.49	5.14
32	0.68	1.03	1.75	2.47	3.14	3.98	4.55
33	0.63	0.94	1.55	2.15	2.72	3.30	3.90
34	0.33	0.60	1.12	1.65	2.12	2.62	3.13
35	0.29	0.50	0.98	1.40	1.84	2.28	2.72
36	0.23	0.38	0.73	1.05	1.37	1.73	2.05
37	0.14	0.23	0.43	0.63	0.83	1.03	1.25
38	0.08	0.10	0.15	0.20	0.25	0.30	0.35
39	0.03	0.03	0.05	0.08	0.08	0.12	0.13

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 12.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1.$

D = 0.500 ft for top and bottom
D = 0.283 ft for sides.

Table 15

Pressure Data

Conduit with Axis 20 Degrees from Normal to Face of Dam

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.56	1.55	3.58	5.51	7.49	9.46	11.36
2	0.13	0.62	1.60	2.53	3.58	4.43	5.43
3	0.00	0.30	0.95	1.49	2.15	2.75	3.32
4	-0.07	0.14	0.54	0.89	1.34	1.63	1.96
5	-0.13	-0.07	0.10	0.23	0.31	0.42	0.51
6	-0.10	-0.01	0.19	0.37	0.53	0.67	0.79
7	-0.08	0.04	0.27	0.54	0.71	0.94	1.17
8	-0.03	0.14	0.45	0.78	1.05	1.37	1.67
9	1.62	2.82	5.25	7.66	10.10	12.55	14.97
10	1.45	2.55	4.78	6.95	9.15	11.43	13.58
11	1.32	2.27	4.27	6.24	8.19	10.24	12.14
12	1.15	1.95	3.64	5.26	6.89	8.57	10.22
13	0.96	1.63	2.98	4.28	5.63	7.01	8.34
14	0.83	1.35	2.43	3.46	4.56	5.58	6.66
15	0.77	1.23	2.18	3.04	3.95	4.88	5.75
16	0.62	0.90	1.54	1.99	2.38	3.28	3.75
17	0.58	0.83	1.35	1.79	2.35	2.85	3.35
18	0.93	1.92	3.95	5.86	7.81	10.03	11.88
19	0.66	1.30	2.64	3.91	5.15	6.55	7.77
20	0.57	1.08	2.10	3.20	4.28	5.25	6.23
21	0.54	1.03	2.05	3.04	4.04	4.98	5.95
22	0.42	0.78	1.49	2.22	2.97	3.64	4.33
23	0.35	0.64	1.20	1.78	2.32	2.78	3.43
24	0.75	1.94	4.31	6.66	8.99	11.36	13.74
25	0.04	0.40	1.18	1.93	2.53	3.35	4.08
26	-0.18	-0.14	-0.04	0.04	0.19	0.18	0.36
27	-0.11	-0.04	0.14	0.32	0.46	0.59	0.72
28	0.03	0.15	0.48	0.83	1.15	1.42	1.85
29	1.65	2.85	5.35	7.81	10.30	12.80	15.25
30	1.31	2.26	4.23	6.07	7.99	10.12	11.99
31	0.95	1.54	2.81	3.91	5.10	6.51	7.61
32	0.79	1.27	2.30	3.20	4.10	5.13	6.03
33	0.60	0.87	1.43	1.95	2.48	3.05	3.60
34	0.33	0.55	1.08	1.59	2.10	2.60	3.15
35	0.28	0.48	0.92	1.38	1.82	2.25	2.70
36	0.23	0.38	0.70	1.05	1.37	1.69	2.05
37	0.15	0.23	0.44	0.62	0.82	1.03	1.23
38	0.07	0.08	0.13	0.18	0.23	0.29	0.35
39	0.02	0.03	0.04	0.05	0.06	0.10	0.15

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 13.

Equation for entrance curves: $\frac{X}{D^2} + \frac{Y}{(D/3)^2} = 1.$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 16

Pressure Data

Conduit with Axis 30 Degrees from Normal to Face of Dam

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.62	1.70	3.82	5.92	8.02	10.18	12.22
2	-0.04	0.26	0.82	1.36	1.92	2.42	3.05
3	-0.12	0.00	0.29	0.62	0.80	1.08	1.52
4	-0.14	-0.12	0.00	0.16	0.18	0.25	0.46
5	-0.17	-0.16	-0.12	-0.10	-0.10	-0.13	-0.06
6	-0.11	-0.07	0.04	0.18	0.24	0.33	0.53
7	-0.06	0.04	0.24	0.50	0.64	0.84	1.10
8	0.00	0.15	0.50	0.85	1.14	1.48	1.85
9	1.64	2.86	5.32	7.78	10.28	12.75	15.20
10	1.54	2.74	5.14	7.55	9.99	12.39	14.80
11	1.46	2.58	4.89	7.14	9.49	11.76	14.03
12	1.34	2.37	4.48	6.56	8.68	10.77	12.91
13	1.22	2.11	3.98	5.80	7.68	9.54	11.38
14	1.10	1.86	3.47	5.06	6.70	8.28	9.80
15	0.99	1.66	3.05	4.40	5.82	7.19	8.54
16	0.85	1.36	2.50	3.55	4.70	5.80	6.82
17	0.72	1.14	1.98	2.84	3.68	4.49	5.35
18	0.96	2.02	4.44	6.21	8.42	10.54	12.66
19	0.62	1.29	2.74	3.82	5.19	6.43	7.62
20	0.58	1.18	2.46	3.51	4.71	5.78	6.94
21	0.62	1.15	2.25	3.34	4.49	5.54	6.62
22	0.46	0.85	1.62	2.42	3.20	3.98	4.74
23	0.40	0.72	1.40	2.05	2.72	3.38	4.08
24	0.75	1.94	4.32	6.69	9.09	11.42	13.84
25	0.04	0.38	1.06	1.59	2.34	3.04	3.65
26	-0.26	-0.36	-0.50	-0.63	-0.86	-0.96	-1.12
27	-0.11	-0.06	0.06	0.22	0.28	0.39	0.56
28	0.02	0.22	0.62	1.06	1.39	1.88	2.35
29	1.64	2.86	5.35	7.84	10.34	12.82	15.32
30	1.46	2.59	4.89	7.16	9.46	11.76	14.04
31	1.21	2.10	3.95	5.70	7.58	9.38	11.10
32	1.00	1.68	3.09	4.49	5.94	7.29	8.68
33	0.74	1.18	2.08	2.98	3.85	4.72	5.69
34	0.32	0.59	1.12	1.66	2.18	2.70	3.22
35	0.28	0.52	0.98	1.42	1.88	2.36	2.78
36	0.22	0.39	0.74	1.08	1.42	1.79	2.14
37	0.15	0.25	0.45	0.66	0.86	1.08	1.30
38	0.08	0.10	0.15	0.21	0.27	0.32	0.39
39	0.02	0.03	0.05	0.08	0.08	0.12	0.16

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 14.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1.$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 17

Pressure Data

Conduit with Axis 40 Degrees from Normal to Face of Dam

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.58	1.61	3.71	5.56	7.81	9.86	11.78
2	-0.42	-0.58	-0.82	-1.15	-1.42	-1.72	-1.79
3	-0.28	-0.30	-0.32	-0.32	-0.45	-0.52	-0.42
4	-0.22	-0.24	-0.28	-0.26	-0.28	-0.36	-0.43
5	-0.20	-0.20	-0.22	-0.14	-0.22	-0.27	-0.44
6	-0.16	-0.16	-0.08	-0.04	-0.02	-0.01	0.04
7	-0.08	-0.01	0.24	0.47	0.60	0.74	1.04
8	0.00	0.15	0.49	0.90	1.20	1.50	1.90
9	1.62	2.84	5.34	7.84	10.32	12.84	15.32
10	1.56	2.78	5.25	7.78	10.20	12.70	15.16
11	1.52	2.72	5.16	7.62	10.04	12.46	14.94
12	1.44	2.62	5.02	7.37	9.68	12.08	14.48
13	1.38	2.48	4.76	7.01	9.24	11.46	13.68
14	1.32	2.33	4.50	6.58	8.63	10.70	12.82
15	1.22	2.15	4.10	6.06	7.88	9.80	11.75
16	1.02	1.75	3.28	4.82	6.22	7.65	9.22
17	0.82	1.35	2.45	3.60	4.62	5.58	6.80
18	0.92	1.92	4.02	6.14	8.24	10.46	12.53
19	0.66	1.42	2.86	4.40	5.81	7.36	8.69
20	0.64	1.30	2.64	4.00	5.30	6.67	7.90
21	0.70	1.35	2.72	4.08	5.40	6.70	8.04
22	0.52	1.05	2.00	3.00	3.92	4.92	5.86
23	0.42	0.80	1.46	2.22	2.84	3.58	4.29
24	0.76	1.96	4.35	6.71	9.08	11.51	13.90
25	-0.46	-0.78	-1.12	-1.88	-2.29	-2.64	-2.90
26	-0.30	-0.44	-0.68	-0.94	-1.21	-1.46	-1.59
27	-0.12	-0.06	0.04	0.12	0.22	0.24	0.59
28	0.00	0.15	0.48	0.85	1.16	1.42	1.85
29	1.62	2.84	5.34	7.87	10.34	12.87	15.34
30	1.52	2.72	5.18	7.62	10.09	12.46	14.96
31	1.38	2.46	4.72	6.94	9.15	11.38	13.51
32	1.22	2.15	4.12	6.02	7.88	9.92	11.69
33	0.82	1.38	2.45	3.54	4.54	5.58	6.64
34	0.32	0.58	1.09	1.68	2.14	2.62	3.20
35	0.28	0.50	0.96	1.42	1.86	2.28	2.82
36	0.22	0.40	0.75	1.10	1.48	1.80	2.19
37	0.15	0.25	0.44	0.65	0.85	1.05	1.26
38	0.08	0.08	0.12	0.18	0.24	0.26	0.34
39	0.02	0.02	0.02	0.05	0.08	0.09	0.12

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 15.

Equation of entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1.$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 18

Pressure Data

Conduit with Axis 10 Degrees from Normal to Face of Dam

Semiminor Axis of Entrance Curve Parallel to Face of Dam

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.71	1.69	3.74	5.94	8.09	10.59	12.24
2	0.47	1.19	2.64	4.24	5.79	7.14	8.74
3	0.31	0.86	1.98	3.08	4.28	5.43	6.48
4	0.11	0.39	1.11	1.81	2.41	3.06	3.71
5	0.01	0.16	0.63	1.03	1.48	1.88	2.23
6	-0.04	0.09	0.49	0.74	1.14	1.39	1.67
7	0.00	0.10	0.40	0.79	1.15	1.35	1.70
8	0.03	0.15	0.55	1.00	1.40	1.75	2.10
9	1.57	2.67	4.97	7.37	9.72	12.02	14.32
10	1.39	2.29	4.29	6.24	8.24	10.27	12.14
11	1.15	3.40	3.55	5.25	6.90	8.45	10.00
12	0.96	1.53	2.78	4.05	5.33	6.51	2.63
13	0.77	1.17	2.07	2.85	3.87	4.67	5.57
14	0.66	0.96	1.61	2.41	3.06	3.76	4.36
15	0.60	0.90	1.55	2.15	2.85	3.40	4.00
16	0.65	0.93	1.55	2.45	2.80	3.90	3.95
17	0.60	0.85	1.45	2.00	2.60	3.15	2.99
18	1.05	2.03	4.05	6.00	7.65	10.20	11.95
19	0.70	1.27	2.67	3.93	5.23	6.42	7.62
20	0.56	1.04	2.09	3.14	4.19	5.14	6.09
21	0.50	0.88	1.75	2.65	3.45	4.25	5.15
22	0.40	0.65	1.40	2.10	2.25	3.45	4.10
23	0.38	0.60	1.25	1.85	2.40	3.05	3.65
24	0.74	1.76	3.89	6.19	8.29	10.59	13.40
25	-0.07	0.79	2.94	4.79	6.49	8.04	9.49
26	-0.02	0.11	0.41	0.81	1.11	1.31	1.61
27	-0.04	0.09	0.39	0.69	0.99	1.24	-1.59
28	-0.05	0.05	0.25	0.55	0.80	0.90	1.30
29	1.57	2.74	5.12	7.57	10.02	12.37	14.67
30	0.58	1.70	3.30	4.65	6.25	7.60	9.00
31	0.74	1.07	1.92	2.72	3.52	4.26	5.12
32	0.63	0.40	1.55	2.10	2.80	3.40	3.95
33	0.55	0.75	1.15	1.60	2.05	2.45	2.85
34	0.35	0.60	1.10	1.65	2.20	2.70	3.20
35	0.28	0.50	0.95	1.35	1.80	2.25	2.65
36	0.23	0.35	0.70	1.00	1.40	1.70	2.05
37	0.13	0.10	0.30	0.35	0.50	0.65	8.50
38	0.08	0.00	0.10	0.20	0.25	0.35	0.40
39	0.03	-0.05	0.00	0.00	0.00	0.00	0.50

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 12.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1.$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 19

Pressure Data

Conduit with Axis 30 Degrees from Normal to Face of Dam
Y Axis Skewed 30 Degrees

Piez No.	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.51	1.43	3.08	4.86	6.46	8.21	9.83
2	-0.25	-0.27	-0.36	-0.38	-0.58	-0.75	-0.86
3	-0.24	-0.30	-0.27	-0.42	-0.42	-0.47	-0.87
4	-0.21	-0.27	-0.27	-0.42	-0.49	-0.59	-0.72
5	-0.18	-0.21	-0.14	-0.21	-0.21	-0.21	-0.31
6	-0.10	-0.03	0.22	0.34	0.50	0.57	0.85
7	-0.03	0.12	0.47	0.73	1.05	1.25	1.58
8	0.00	0.20	0.63	1.00	1.40	1.77	2.15
9	0.05	0.28	0.77	1.22	1.63	2.08	2.45
10	0.05	0.28	0.70	1.13	1.60	2.03	2.38
11	0.05	0.30	0.78	1.25	1.73	2.19	2.63
12	1.60	2.86	5.30	7.71	10.19	12.66	15.07
13	1.49	2.71	5.08	7.41	9.76	12.15	14.54
14	1.37	2.55	4.76	6.96	9.17	11.43	13.73
15	1.28	2.30	4.30	6.30	8.29	10.29	12.39
16	1.16	2.05	3.77	5.55	7.27	9.00	10.82
17	1.01	1.75	3.20	4.69	6.11	7.54	8.99
18	0.88	1.49	2.69	3.89	5.07	6.25	7.45
19	0.73	1.19	2.12	3.02	3.92	4.78	5.45
20	0.63	0.97	1.64	2.32	2.94	3.58	4.25
21	0.58	0.85	1.44	1.98	2.48	3.04	3.53
22	0.60	0.87	1.40	1.95	2.45	3.00	3.49
23	0.59	0.85	1.40	1.97	2.45	3.00	3.50
24	0.85	1.84	3.84	5.81	7.81	9.74	11.74
25	0.56	1.13	2.31	3.42	4.67	5.74	6.88
26	0.51	1.00	2.03	2.96	3.94	4.91	5.84
27	0.50	0.95	1.85	2.73	3.60	4.45	5.35
28	0.39	0.73	1.42	2.13	2.74	3.45	4.17
29	0.33	0.62	1.20	1.77	2.33	2.88	3.48
30	0.33	0.59	1.13	1.62	2.12	2.60	3.14
31	0.30	0.58	1.09	1.60	2.04	2.50	2.95
32	0.75	1.95	4.16	6.48	8.80	11.03	13.43
33	-0.49	-0.85	-1.55	-2.25		Too low to read	
34	-0.25	-0.30	-0.55	-0.66	-1.01	-1.14	-1.41
35	-0.03	0.17	0.45	0.77	0.95	1.30	1.53
36	0.05	0.29	0.75	1.23	1.64	2.03	2.45
37	0.33	0.57	1.10	1.60	2.13	2.65	3.13
38	0.23	0.37	0.72	1.20	1.39	1.72	2.03
39	0.06	0.09	0.14	0.20	0.29	0.35	0.42

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 18.

Equation for entrance curves: Top and bottom $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1$, D = 0.500 ft

Y axis skewed 30°

Sides $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1$, D = 0.283

Table 20

Pressure Data

Effect of Bulkhead Guides at Entrance
to Conduit with Axis Normal to Face of Dam

Piez Number	H = 1.25 ft Q = 1.06 cfs	H = 2.50 ft Q = 1.54 cfs	H = 5.00 ft Q = 2.20 cfs	H = 7.50 ft Q = 2.75 cfs	H = 10.00 ft Q = 3.23 cfs	H = 12.50 ft Q = 3.48 cfs	H = 15.00 ft Q = 3.83 cfs
1	0.73	1.83	4.06	6.28	8.54	10.72	12.95
2	0.70	1.75	3.84	5.97	8.11	10.14	12.30
3	0.47	1.19	2.67	4.16	5.69	7.14	8.56
4	0.31	0.85	1.91	3.05	4.20	5.28	6.34
5	0.15	0.50	1.26	2.00	2.76	3.44	4.14
6	0.04	0.26	0.76	1.23	1.72	2.16	2.58
7	0.01	0.18	0.59	0.96	1.34	1.72	2.10
8	0.04	0.25	0.72	1.14	1.58	1.98	2.42
9	1.60	2.81	5.18	7.46	9.87	12.23	9.56
10	1.18	1.95	3.52	5.12	6.83	8.36	10.00
11	0.92	1.46	2.56	3.82	4.96	6.12	7.32
12	0.72	1.08	1.82	2.64	3.52	4.26	5.06
13	0.59	0.81	1.38	1.91	2.48	2.96	3.48
14	0.54	0.73	1.17	1.67	2.13	2.52	2.98
15	0.56	0.76	1.20	1.72	2.16	2.60	3.06
16	0.60	0.88	1.46	2.01	2.58	3.15	3.70
17	0.60	0.88	1.44	1.98	2.56	3.10	3.66
18	1.11	2.13	4.29	6.46	8.66	10.85	13.05
19	0.68	1.32	2.58	3.86	5.14	6.34	7.62
20	0.58	1.08	2.09	3.13	4.16	5.14	6.12
21	0.46	0.88	1.69	2.50	3.32	4.08	4.87
22	0.38	0.66	1.24	1.82	2.42	2.96	3.58
23	0.35	0.62	1.15	1.69	2.26	2.80	3.36
24	0.78	1.96	4.36	6.74	9.15	11.54	13.92
25	0.82	1.94	4.26	6.61	8.96	11.26	13.59
26	0.22	0.68	1.58	2.50	3.46	4.34	5.23
27	0.04	0.23	0.67	1.06	1.47	1.90	2.34
28	0.05	0.25	0.70	1.13	1.54	1.96	2.42
29	1.62	2.86	5.39	7.89	10.39	12.86	15.38
30	0.82	1.24	2.09	2.96	3.84	4.63	5.50
31	0.61	0.88	1.36	1.90	2.36	2.88	3.45
32	0.58	0.79	1.25	1.62	2.05	2.49	2.92
33	0.58	0.85	1.38	1.92	2.44	2.96	3.49
34	0.32	0.58	1.06	1.56	2.07	2.55	3.05
35	0.28	0.50	0.92	1.34	1.80	2.22	2.67
36	0.22	0.38	0.70	1.02	1.36	1.70	2.02
37	0.14	0.22	0.42	0.62	0.83	1.04	1.26
38	0.08	0.07	0.12	0.18	0.23	0.30	0.36
39	0.01	0.01	0.02	0.03	0.08	0.10	0.14

Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 1.
Tests were conducted with a 0.05-ft by 0.05-ft molding on the face of the dam along the sides and bottom of the entrance set back 0.05 ft from point of curvature of entrance curves.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1$

D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.

Table 21

Pressure Data

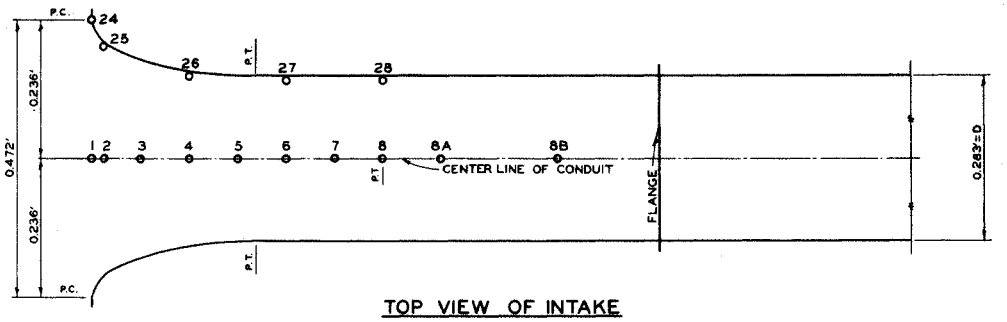
Type A Entrance Curve with Various Depths of Approach Channel

Number	H = 5.0 ft; Q = 2.20 cfs			H = 10.0 ft; Q = 3.23 cfs			H = 15.0 ft; Q = 3.83 cfs		
	Approach Channel 1.75 ft below Invert	Approach Channel 0.50 ft below Invert	Approach Channel 0.1667 ft below Invert	Approach Channel 1.75 ft below Invert	Approach Channel 0.50 ft below Invert	Approach Channel 0.1667 ft below Invert	Approach Channel 1.75 ft below Invert	Approach Channel 0.50 ft below Invert	Approach Channel 0.1667 ft below Invert
1	4.15	4.13	4.05	8.63	8.75	8.57	13.13	13.28	13.14
2	3.67	3.41	3.25	7.71	7.25	6.95	11.82	10.93	10.14
3	2.82	2.89	2.76	5.85	6.15	5.89	8.94	9.31	9.06
4	2.06	2.03	1.96	4.31	4.39	4.21	6.63	6.77	6.55
5	1.31	1.30	1.34	2.85	3.05	2.91	4.35	4.77	3.91
6	0.81	0.77	0.70	1.84	1.72	1.72	2.79	2.80	1.82
7	0.64	0.76	0.73	1.48	1.69	1.66	2.22	2.64	1.82
8	0.77	0.83	0.81	1.68	1.88	1.82	2.55	2.84	2.84
8-A	1.03	0.91	0.91	2.17	2.00	2.00	3.20	3.05	3.07
8-B	1.10	0.98	0.98	2.33	2.10	2.12	3.38	3.24	3.30
9	5.07	5.05	5.23	9.73	9.88	10.06	14.46	14.34	14.93
10	3.53	3.63	3.91	6.70	6.97	7.55	10.02	10.16	9.48
11	2.63	2.76	2.96	4.99	5.28	5.59	7.37	7.71	8.35
12	1.89	1.99	2.10	3.52	3.72	3.94	5.07	5.46	5.78
13	1.39	1.34	1.46	2.53	2.53	2.66	3.58	3.64	3.89
14	1.24	1.23	1.31	2.22	2.20	2.31	3.02	3.17	3.30
15	1.29	1.39	1.42	2.25	2.49	2.51	3.18	3.54	3.61
16	1.53	1.43	1.43	2.67	2.54	2.25	3.81	3.63	3.69
17	1.50	1.48	1.45	2.66	2.60	2.59	3.77	3.71	3.72
18	4.19	4.20	4.14	8.22	8.44	8.30	12.30	12.66	12.48
19	2.59	2.68	2.64	5.04	5.31	5.28	7.95	7.95	7.90
20	2.14	2.05	2.04	4.20	4.07	4.07	6.32	6.24	6.09
21	1.74	1.84	1.85	3.37	3.69	3.68	5.12	5.55	5.58
22	1.30	1.39	1.37	2.48	2.81	2.73	3.75	4.17	4.21
23	1.25	1.21	1.21	2.34	2.38	2.35	3.53	3.52	3.51
24	4.43	4.34	4.35	9.21	9.06	9.06	14.19	13.88	13.77
25	4.16	3.71	3.59	8.60	7.94	7.66	13.17	11.86	11.69
26	1.75	1.62	1.49	3.66	3.57	3.32	5.49	5.54	5.16
27	0.75	0.75	0.71	1.57	1.72	1.64	2.51	2.67	2.56
28	0.77	0.83	0.83	1.67	1.90	1.89	2.50	2.85	2.90
29	5.30	5.26	5.17	10.17	9.98	9.97	15.09	14.68	14.70
30	2.30	2.30	2.53	4.16	4.30	4.77	6.12	6.31	7.12
31	1.39	1.20	1.21	2.43	1.94	2.11	3.46	2.73	3.03
32	1.28	1.30	1.32	2.17	2.30	2.33	2.99	3.26	3.37
33	1.47	1.42	1.45	2.51	2.49	2.58	3.62	3.62	3.66
34	1.17	1.03	1.05	2.19	1.98	2.05	3.25	2.84	3.00
35	0.99	0.90	0.88	1.84	1.71	1.73	2.75	2.49	2.58
36	0.75	0.67	0.66	1.40	1.29	1.28	2.09	1.88	1.99
37	0.46	0.40	0.40	0.85	0.78	0.41	1.27	1.11	1.17
38	0.16	0.10	0.08	0.28	0.14	0.17	0.40	0.17	0.21
39	0.03	0.02	0.01	0.03	0.02	-0.01	0.02	-0.04	0.03

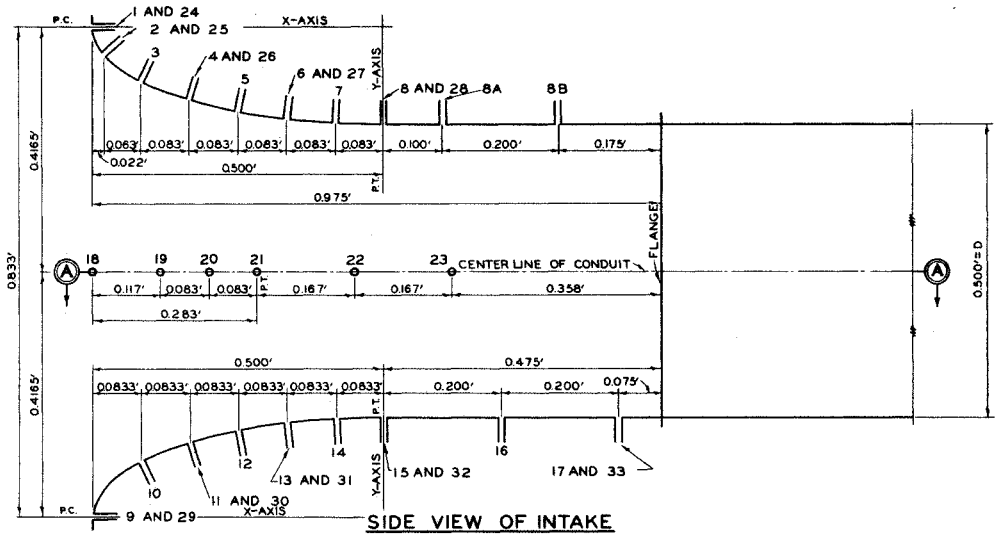
Notes: Pressures in feet of water.
H = Head in feet of water above center line of conduit.
Q = Discharge in cfs.
Piezometer locations shown on plate 1.

Equation for entrance curves: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1$.

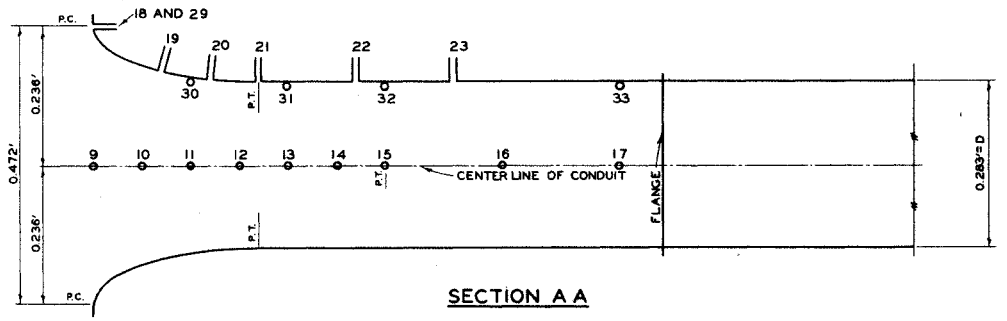
D = 0.500 ft for top and bottom.
D = 0.283 ft for sides.



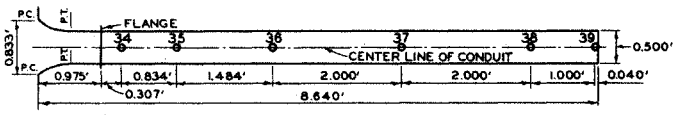
TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



SECTION A A



SIDE VIEW OF CONDUIT

NOTE: DISTANCES SHOWN IN FEET

EQUATION FOR ENTRANCE CURVES: $\frac{X^2}{D^2}+\frac{Y^2}{(0.3)^2}=1$

HORIZONTAL POSITION OF PIEZOMETERS IDENTICAL FOR TYPES A-G ENTRANCES.

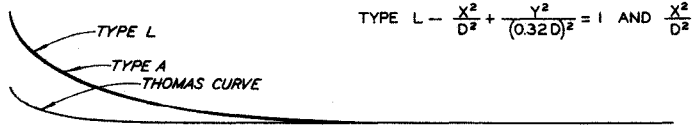
PIEZOMETER LOCATIONS
TYPE A

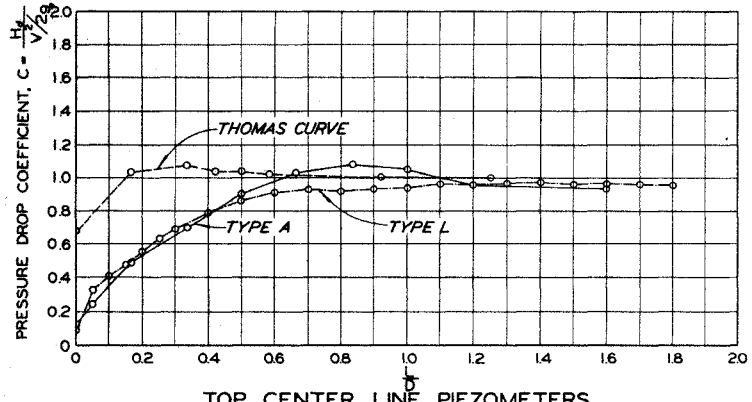
PLATE 1

PLATE 2

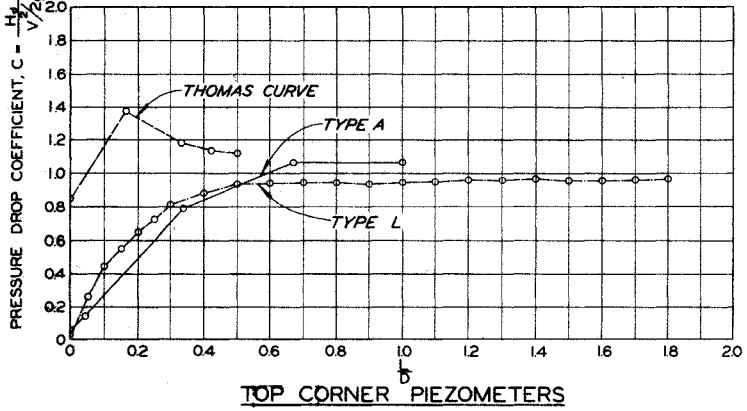
TYPE A — $\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$ D=0.500' FOR TOP AND BOTTOM CURVES
D=0.283' FOR SIDE CURVES

TYPE L — $\frac{X^2}{D^2}+\frac{Y^2}{(0.32D)^2}=1$ AND $\frac{X^2}{D^2}+\frac{Y^2}{(0.16D)^2}=1$

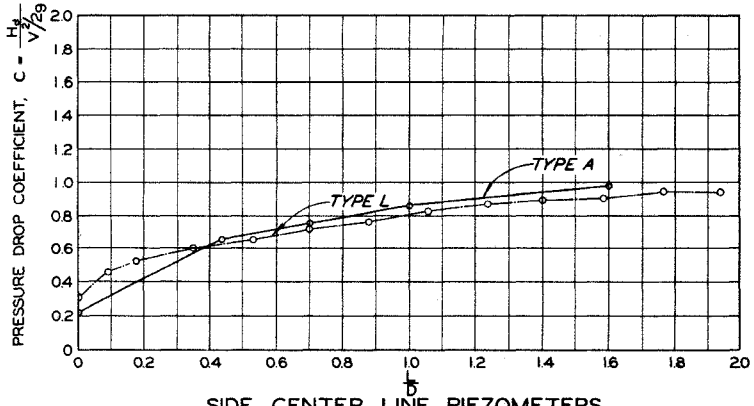




TOP CENTER LINE PIEZOMETERS



TOP CORNER PIEZOMETERS

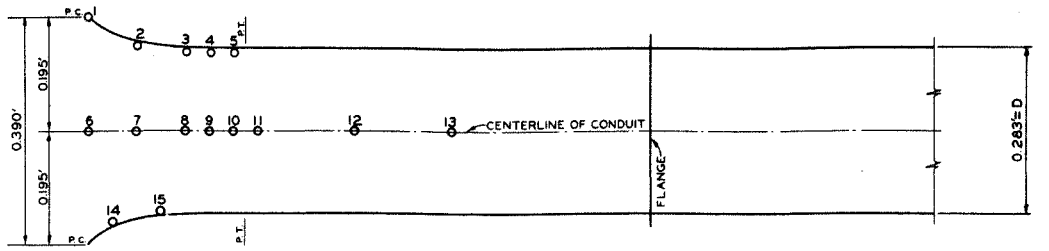


SIDE CENTER LINE PIEZOMETERS

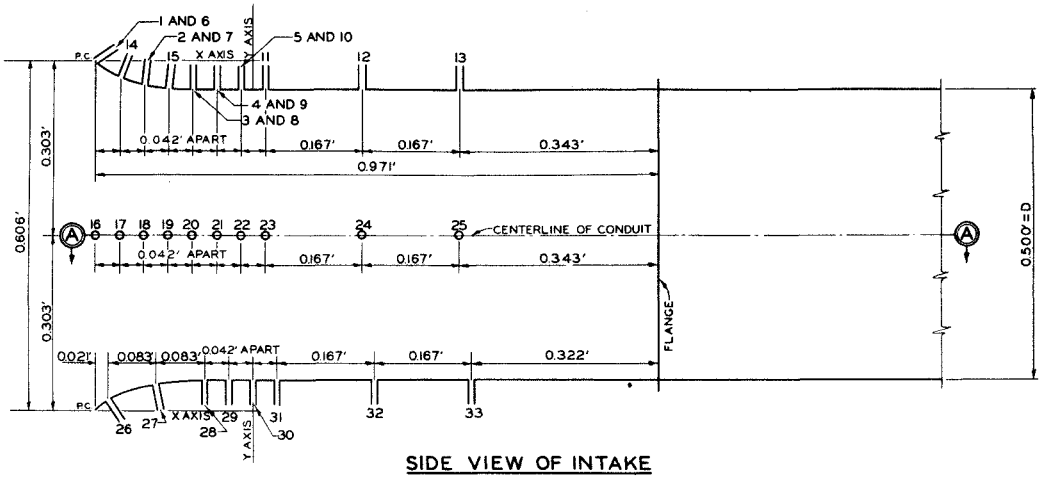
NOTE: H_d = PRESSURE DROP FROM POOL TO PIEZOMETER.
V = AVERAGE VELOCITY IN CONDUIT PROPER.
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED.

PRESSURE DATA

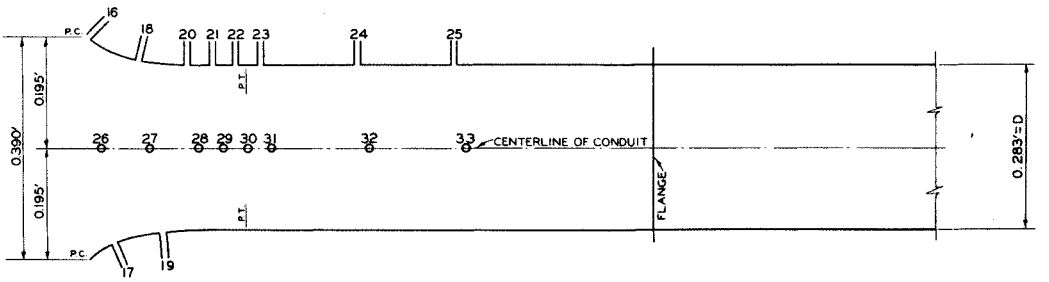
TYPES A, L, AND THOMAS ENTRANCE CURVES



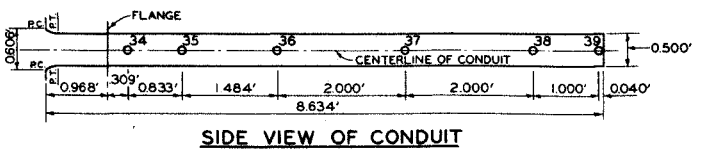
TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



SECTION A A



SIDE VIEW OF CONDUIT

NOTE: DISTANCES SHOWN IN FEET.

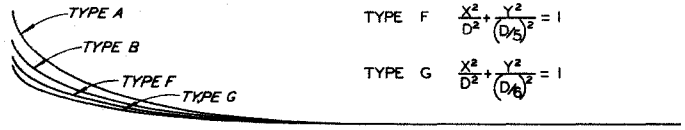
* "DESIGN OF BELLMOUTHS FOR ENTRANCES TO CONDUITS OF CIRCULAR, SQUARE AND RECTANGULAR CROSS SECTIONS" DATED JULY 1946. BY PROF. H. A. THOMAS OF THE CARNEGIE INSTITUTE OF TECHNOLOGY.

PIEZOMETER LOCATIONS

* THOMAS CURVE

PLATE 3

PLATE 4



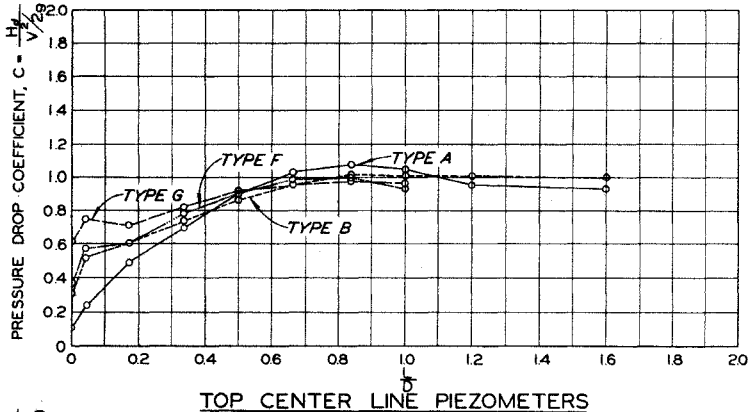
TYPE A $\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$

TYPE B $\frac{X^2}{D^2}+\frac{Y^2}{(D/4)^2}=1$

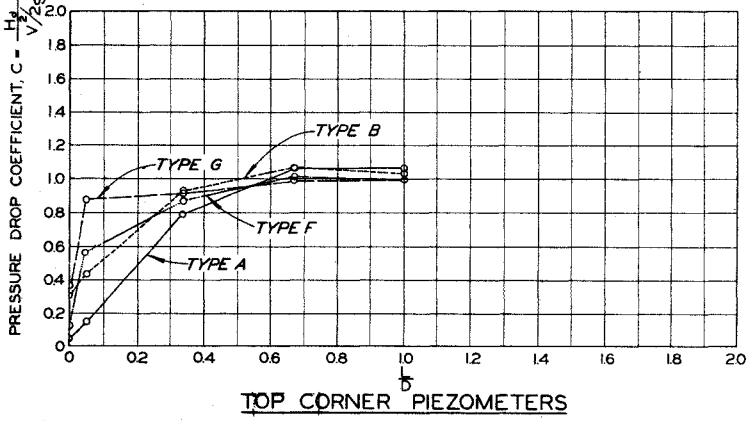
TYPE F $\frac{X^2}{D^2}+\frac{Y^2}{(D/5)^2}=1$

TYPE G $\frac{X^2}{D^2}+\frac{Y^2}{(D/6)^2}=1$

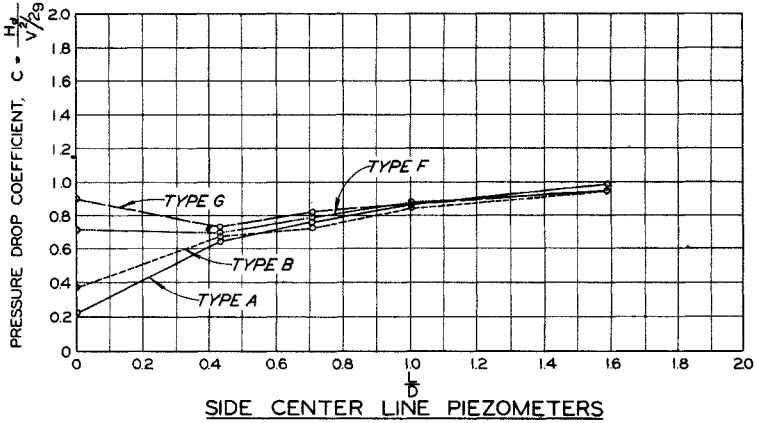
D = 0.500' FOR TOP AND BOTTOM CURVES
D = 0.283' FOR SIDE CURVES



TOP CENTER LINE PIEZOMETERS



TOP CORNER PIEZOMETERS

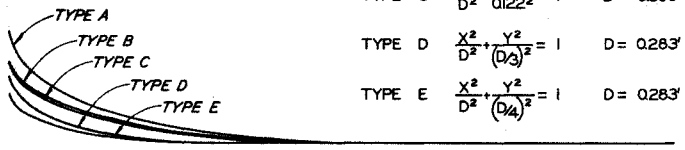


SIDE CENTER LINE PIEZOMETERS

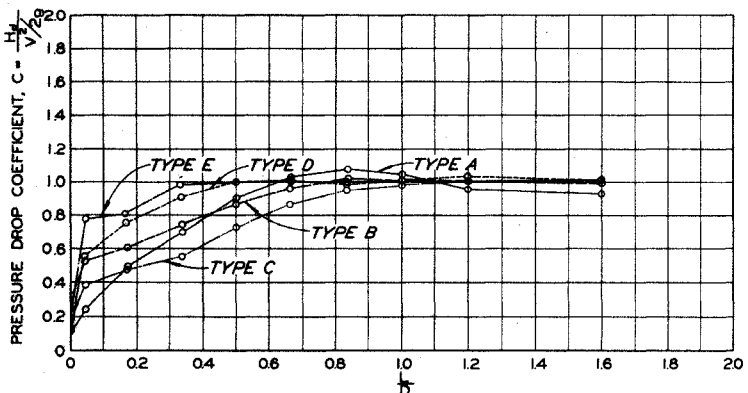
NOTE: H_d = PRESSURE DROP FROM POOL TO PIEZOMETER.
V = AVERAGE VELOCITY IN CONDUIT PROPER.
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED.

PRESSURE DATA

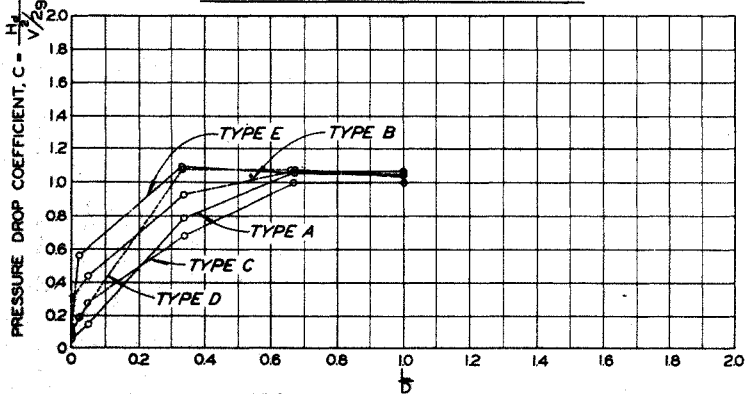
TYPES A, B, F, AND G ENTRANCE CURVES



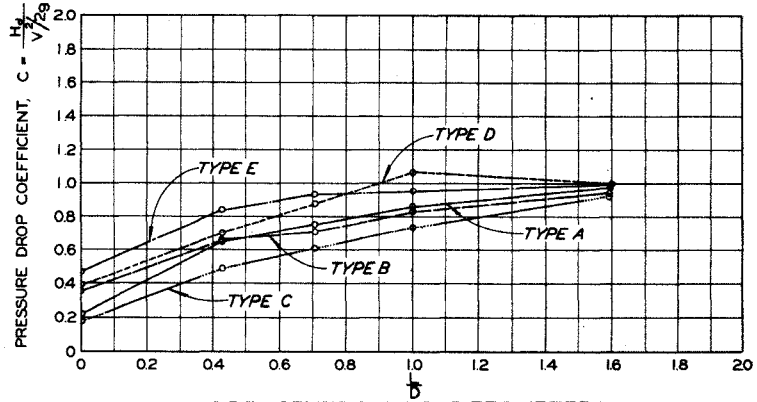
TYPE A	$\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$	D = 0.500′ FOR TOP AND BOTTOM CURVES D = 0.283′ FOR SIDE CURVES
TYPE B	$\frac{X^2}{D^2}+\frac{Y^2}{(D/4)^2}=1$	D = 0.500′ FOR TOP AND BOTTOM CURVES D = 0.283′ FOR SIDE CURVES
TYPE C	$\frac{X^2}{D^2}+\frac{Y^2}{0.122^2}=1$	D = 0.500′ FOR ALL SIDES
TYPE D	$\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$	D = 0.283′ FOR ALL SIDES
TYPE E	$\frac{X^2}{D^2}+\frac{Y^2}{(D/4)^2}=1$	D = 0.283′ FOR ALL SIDES



TOP CENTER LINE PIEZOMETERS



TOP CORNER PIEZOMETERS



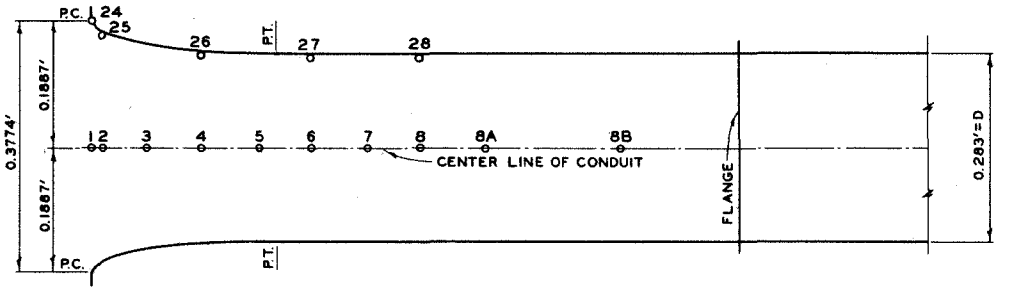
SIDE CENTER LINE PIEZOMETERS

NOTE: H_d = PRESSURE DROP FROM POOL TO PIEZOMETER.
V = AVERAGE VELOCITY IN CONDUIT PROPER.
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED.

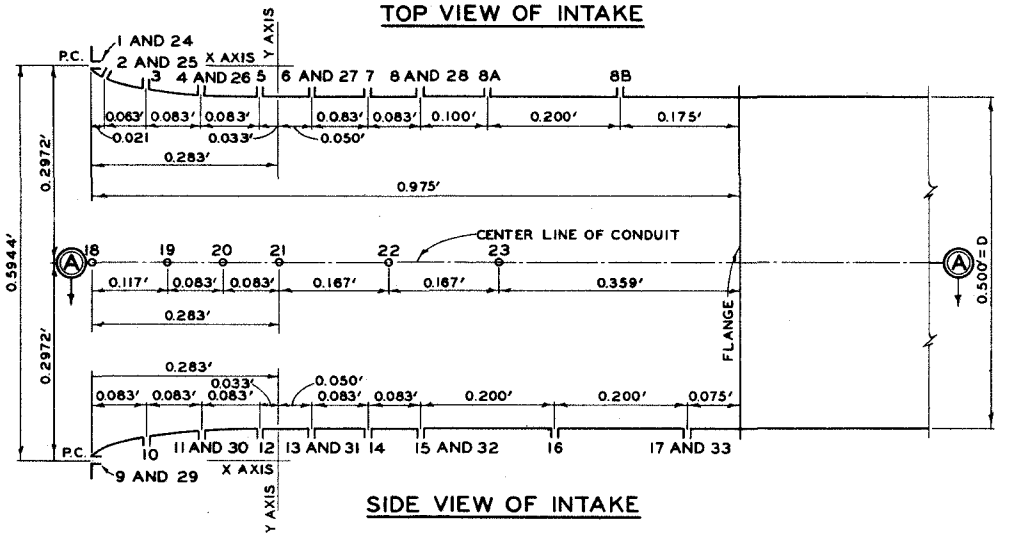
PRESSURE DATA

TYPES A, B, C, D, AND E ENTRANCE CURVES

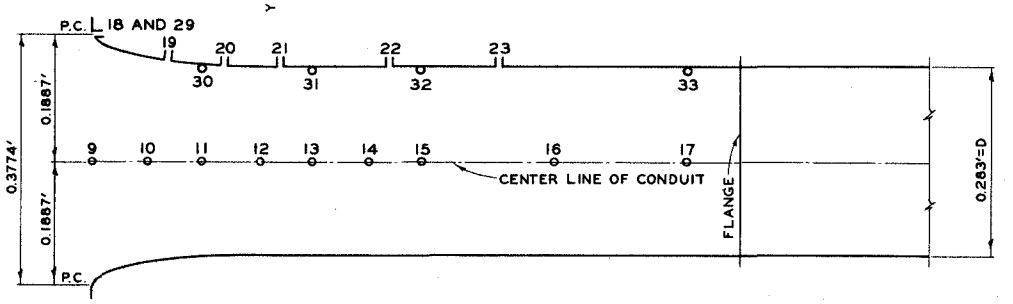
PLATE 5



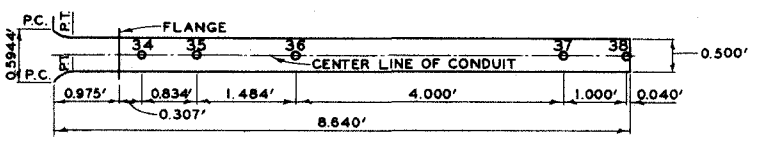
TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



SECTION A A



SIDE VIEW OF CONDUIT

NOTE: DISTANCES SHOWN IN FEET

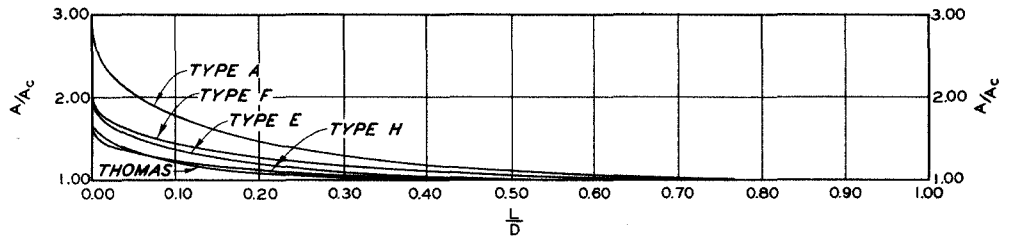
EQUATION FOR ENTRANCE CURVES:

$$\frac{X^2}{D^2}+\frac{Y^2}{(D/6)^2}=1$$

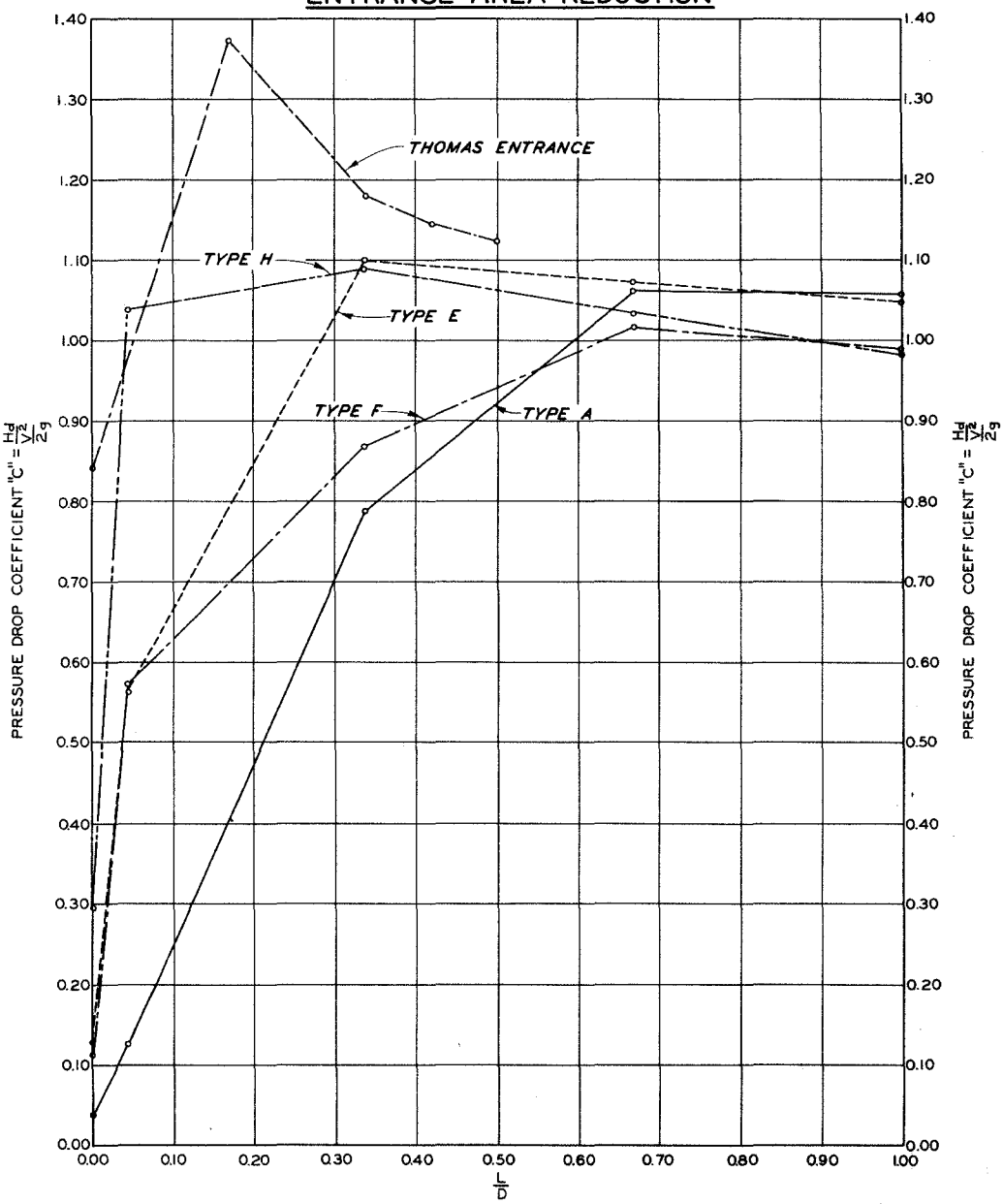
D = 0.283' ALL CURVES

PIEZOMETER LOCATIONS
TYPE H

PLATE 6



ENTRANCE AREA REDUCTION



TOP CORNER PIEZOMETERS

NOTE: A = AREA OF BELLMOUTH OF SECTION IN QUESTION.

A_c = AREA OF CONDUIT

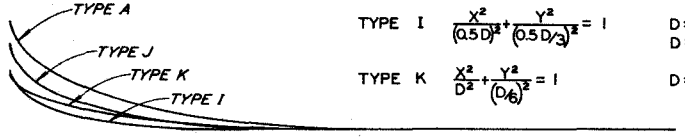
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED

PRESSURE DATA

TYPES A, E, F, H, AND THOMAS ENTRANCE CURVES
TOP CORNER PIEZOMETERS

PLATE 7

PLATE 8

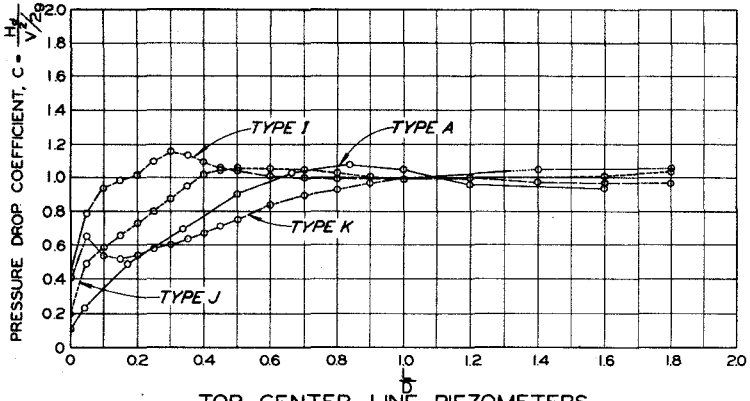


TYPE A $\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$ — D = 0.500' FOR TOP AND BOTTOM CURVES; D = 0.283' FOR SIDE CURVES

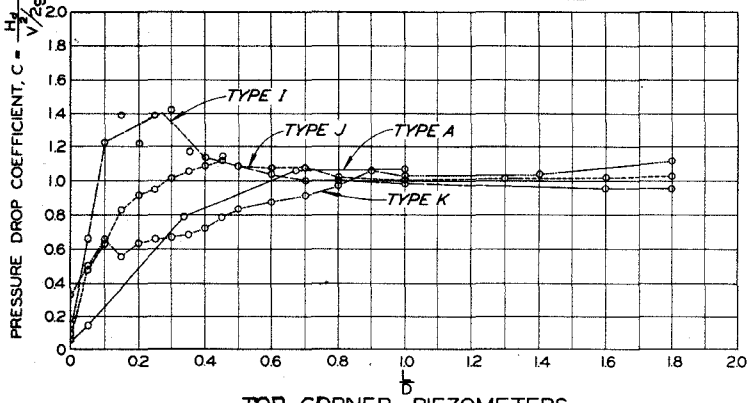
TYPE J $\frac{X^2}{(0.75D)^2}+\frac{Y^2}{(0.75D/3)^2}=1$ — D = 0.500' FOR TOP AND BOTTOM CURVES; D = 0.283' FOR SIDE CURVES

TYPE I $\frac{X^2}{(0.5D)^2}+\frac{Y^2}{(0.5D/3)^2}=1$ — D = 0.500' FOR TOP AND BOTTOM CURVES; D = 0.283' FOR SIDE CURVES

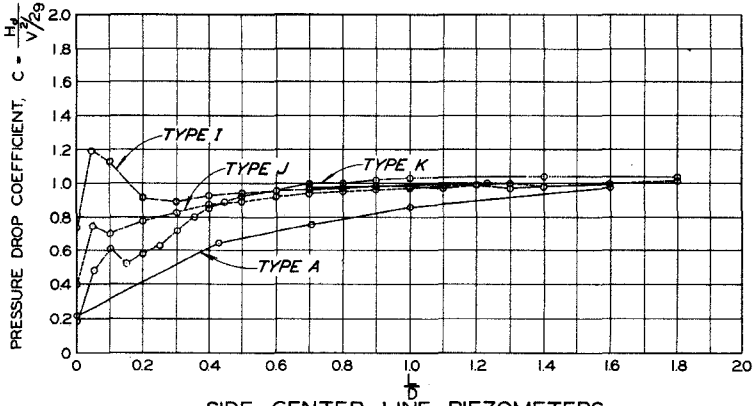
TYPE K $\frac{X^2}{D^2}+\frac{Y^2}{(D/6)^2}=1$ — D = 0.500' FOR ALL SIDES



TOP CENTER LINE PIEZOMETERS



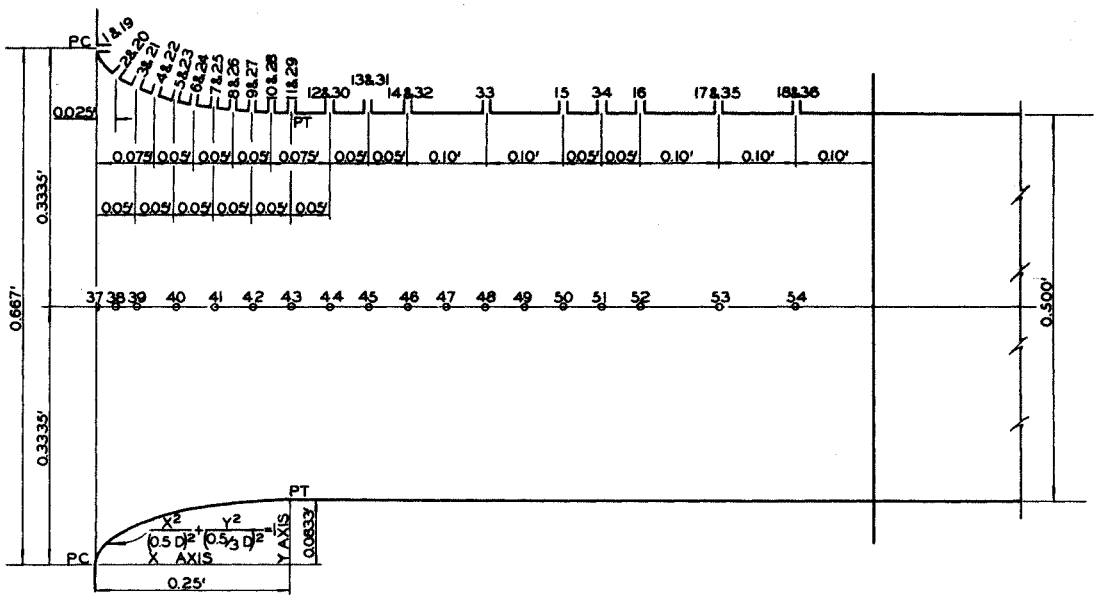
TOP CORNER PIEZOMETERS



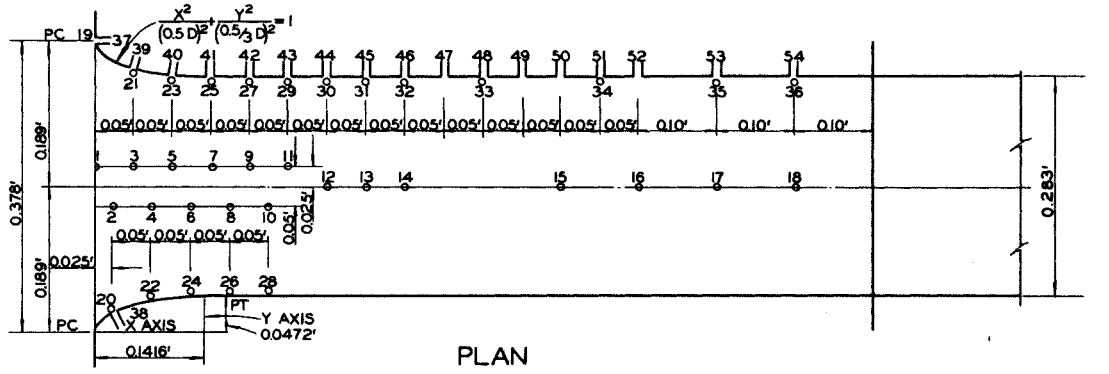
SIDE CENTER LINE PIEZOMETERS

NOTE: H_d = PRESSURE DROP FROM POOL TO PIEZOMETER.
V = AVERAGE VELOCITY IN CONDUIT PROPER.
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED.

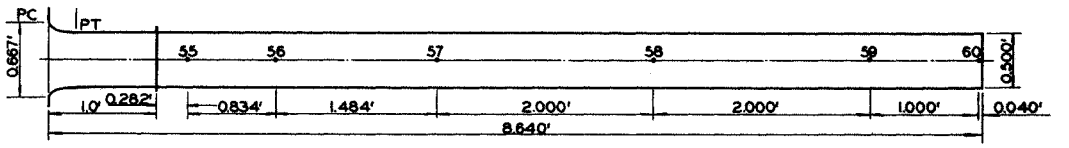
PRESSURE DATA
TYPES A, I, J, AND K ENTRANCE CURVES



ELEVATION



PLAN

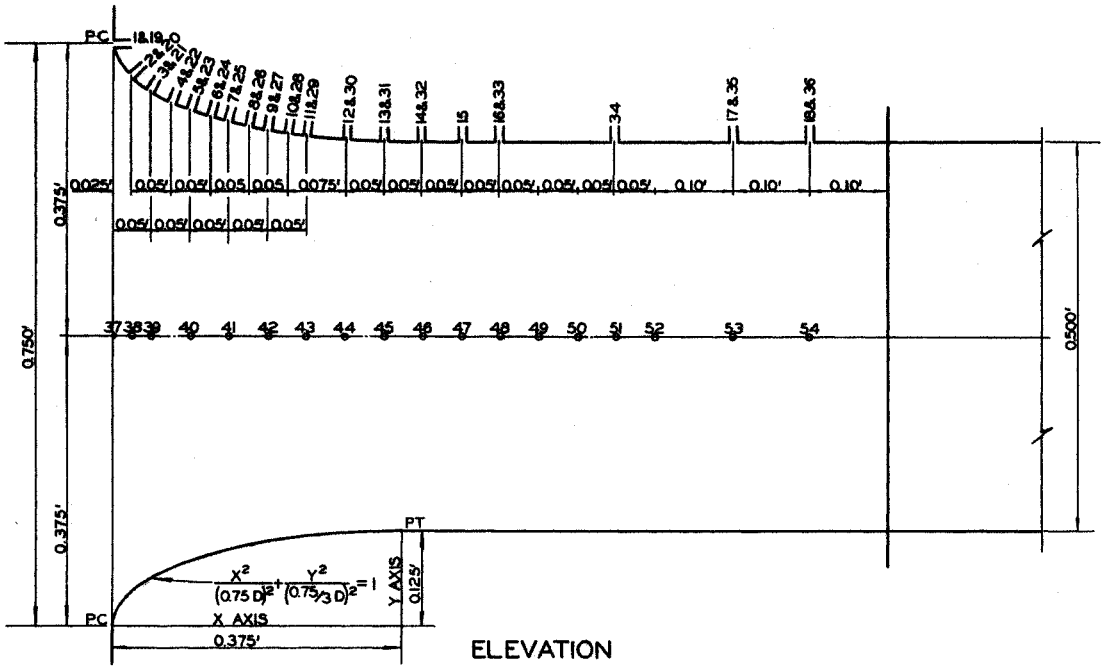


ELEVATION OF CONDUIT

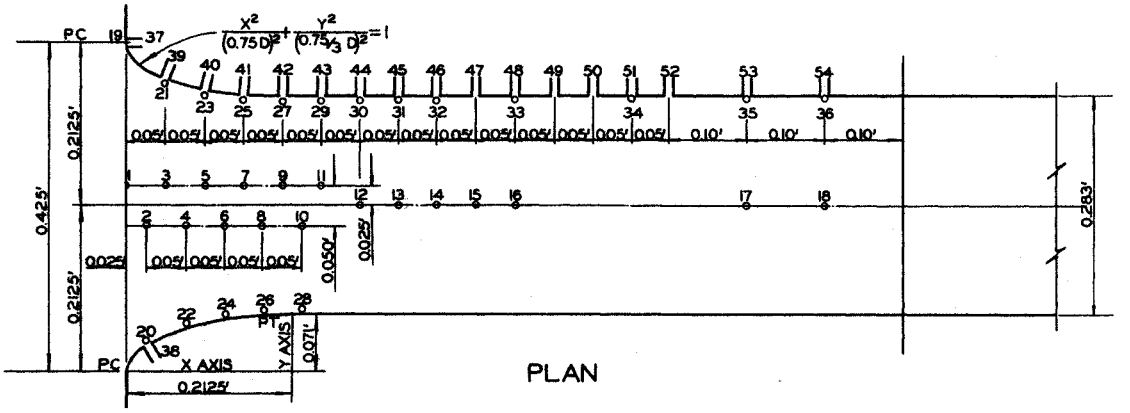
NOTE: DISTANCES SHOWN IN FEET.

PIEZOMETER LOCATIONS
TYPE I

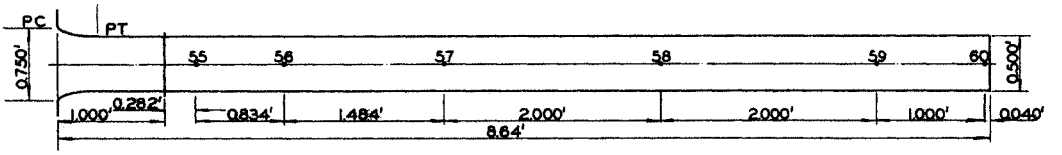
PLATE 9



ELEVATION



PLAN

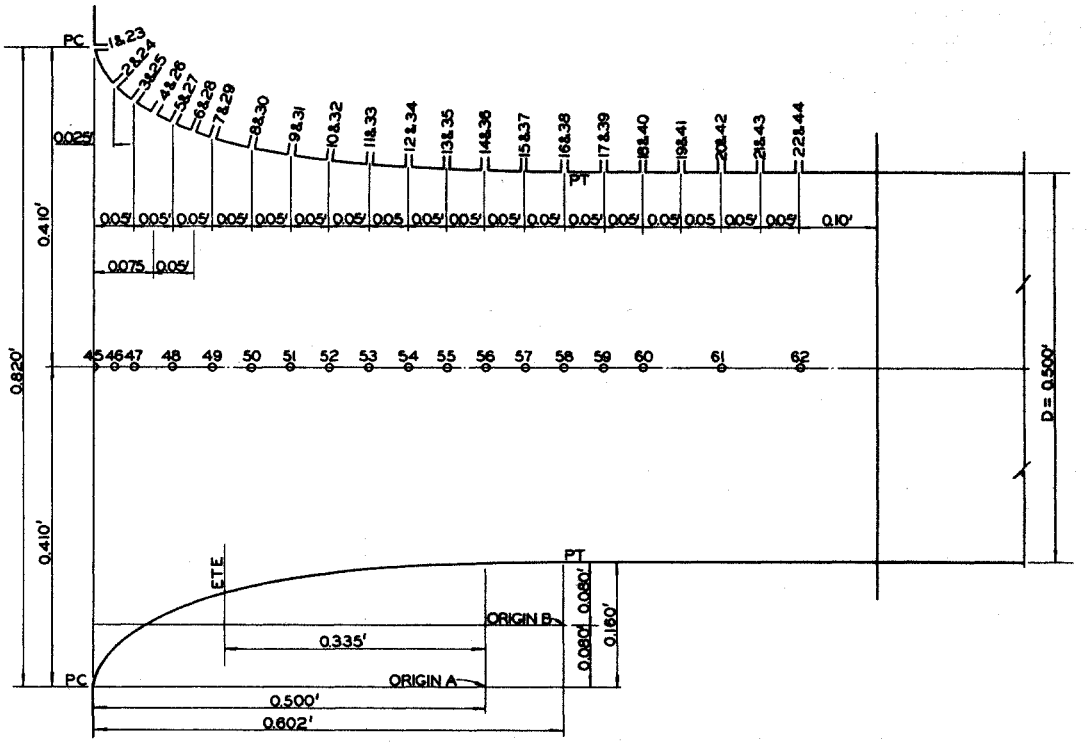


ELEVATION OF CONDUIT

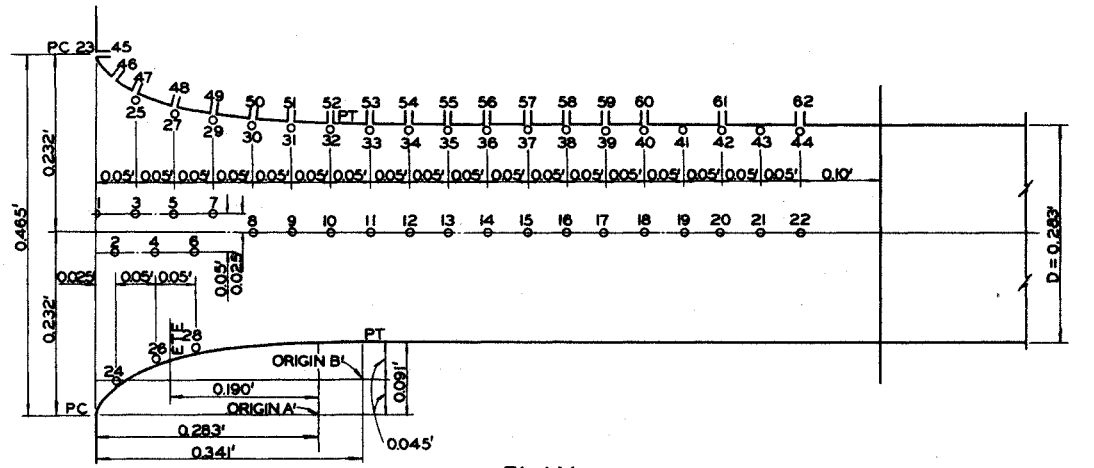
NOTE: DISTANCES ARE SHOWN IN FEET.

PIEZOMETER LOCATIONS
TYPE J

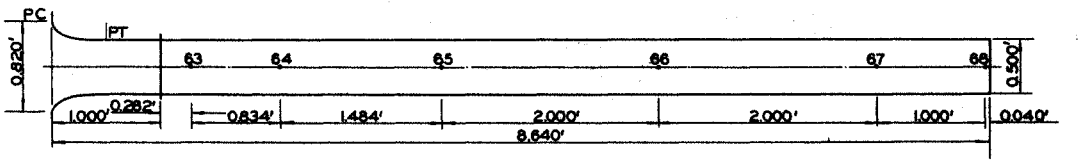
PLATE 10



ELEVATION



PLAN



ELEVATION OF CONDUIT

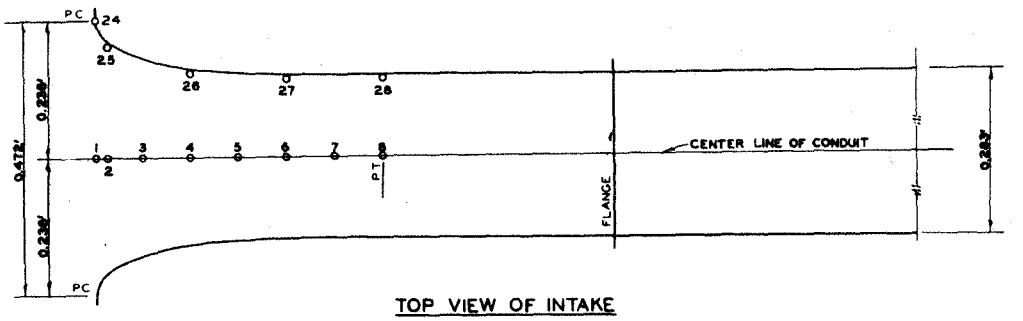
NOTE: DISTANCES SHOWN IN FEET.

EQUATION WITH ORIGIN A & A' $\frac{X^2}{D^2} + \frac{Y^2}{(0.32\,D)^2} = 1$

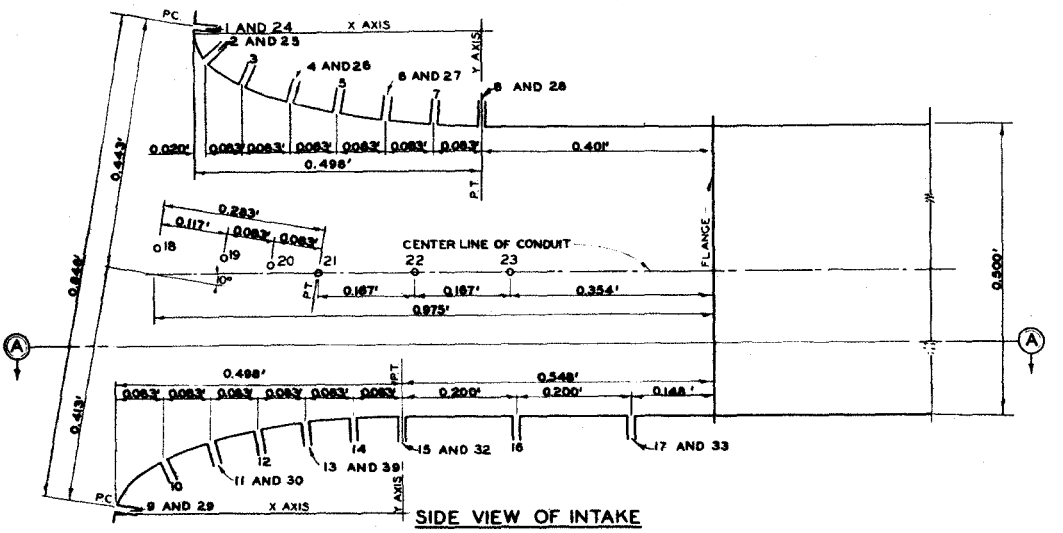
EQUATION WITH ORIGIN B & B' $\frac{X^2}{D^2} + \frac{Y^2}{(0.16\,D)^2} = 1$

PIEZOMETER LOCATIONS
TYPE L

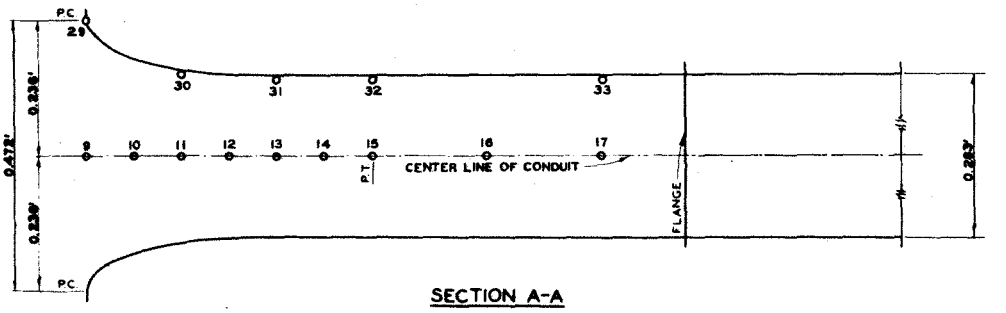
PLATE 11



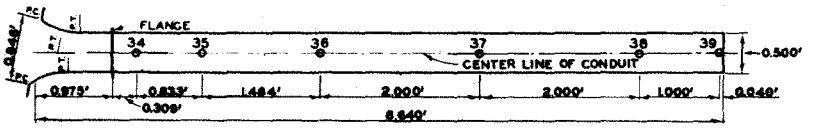
TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



SECTION A-A



SIDE VIEW OF CONDUIT

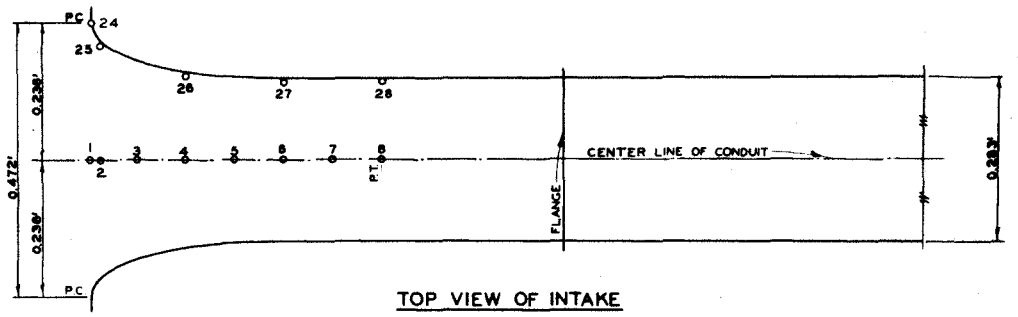
NOTE: DISTANCES SHOWN IN FEET.

EQUATION FOR ENTRANCE CURVES: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1$

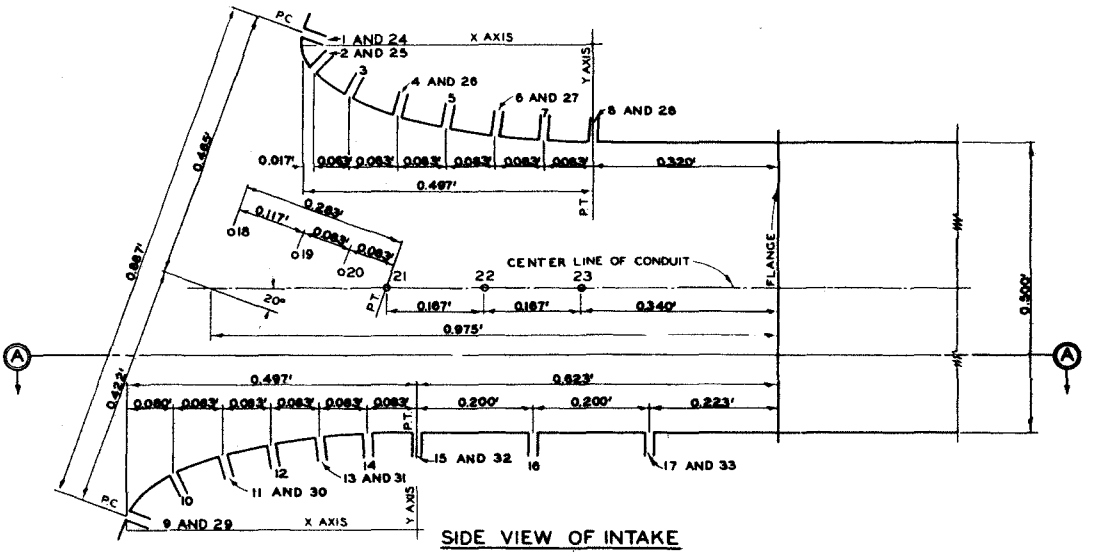
PIEZOMETER LOCATIONS

CONDUIT AXIS 10° FROM NORMAL TO FACE OF DAM

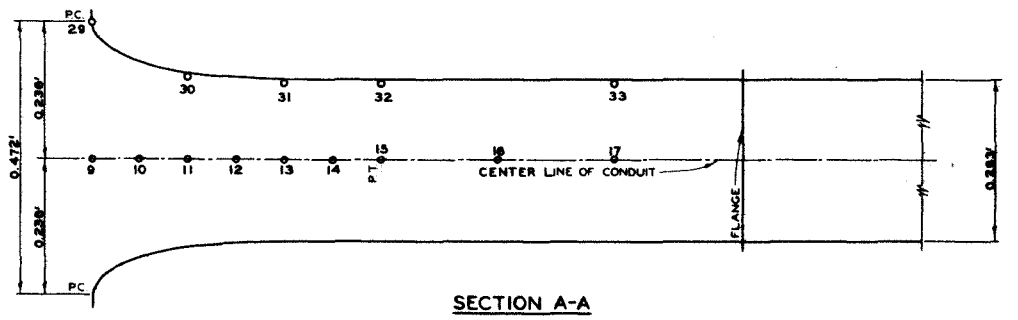
PLATE 12



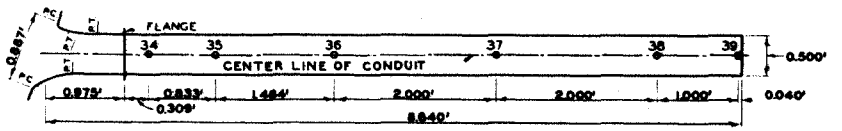
TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



SECTION A-A



SIDE VIEW OF CONDUIT

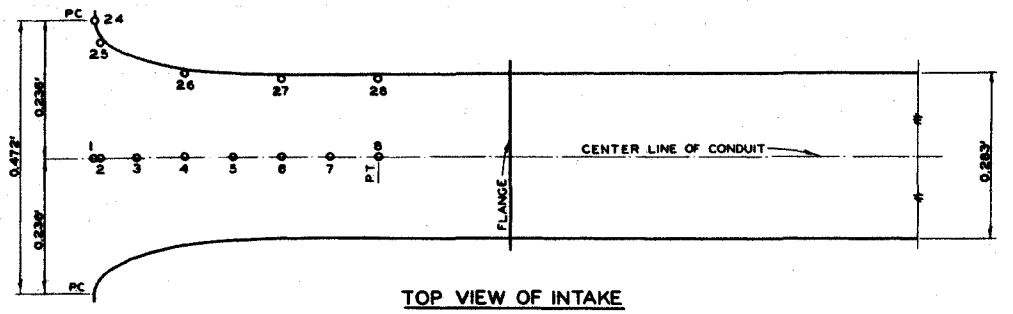
NOTE: DISTANCES SHOWN IN FEET.

EQUATION FOR ENTRANCE CURVES: $\frac{X^2}{D^2} + \frac{Y^2}{(D/3)^2} = 1$

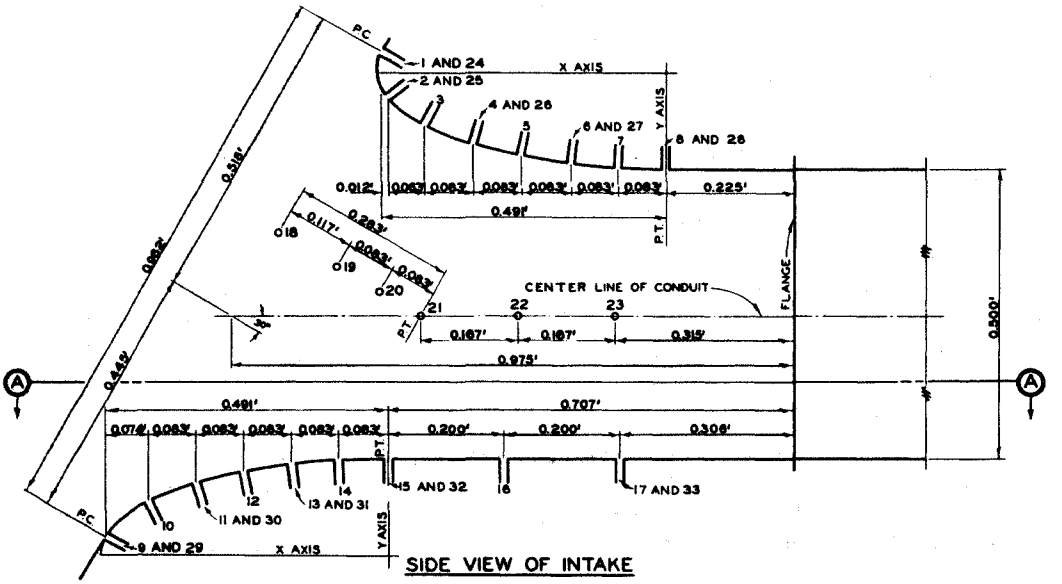
PIEZOMETER LOCATIONS

CONDUIT AXIS 20° FROM NORMAL TO FACE OF DAM

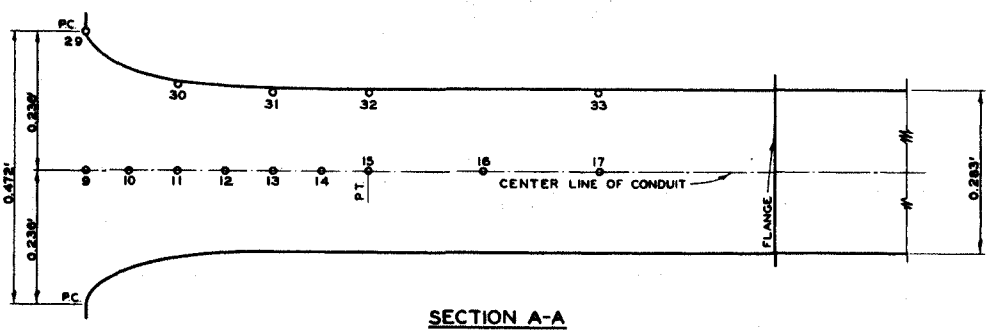
PLATE 13



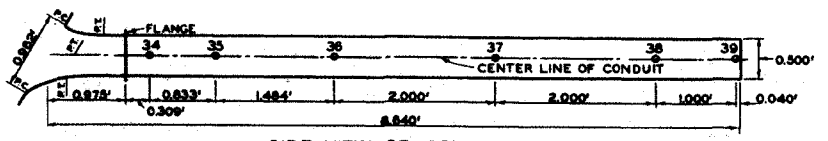
TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



SECTION A-A



SIDE VIEW OF CONDUIT

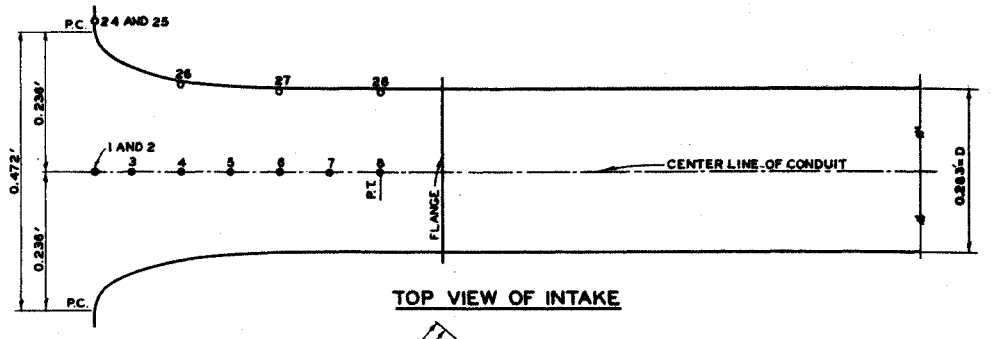
NOTE: DISTANCES SHOWN IN FEET.

EQUATION FOR ENTRANCE CURVES: $\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$

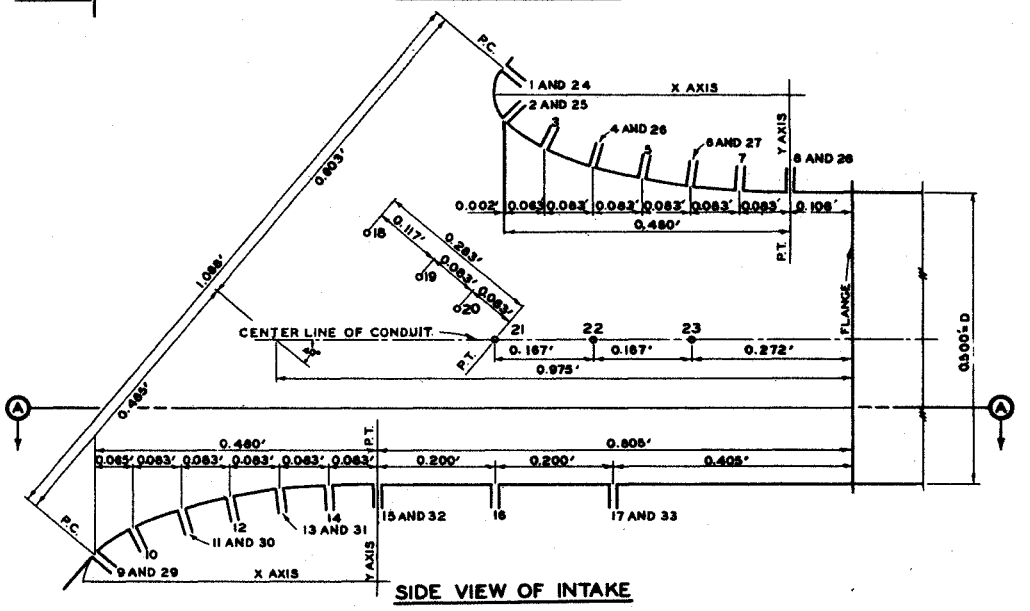
PIEZOMETER LOCATIONS

CONDUIT AXIS 30° FROM NORMAL TO FACE OF DAM

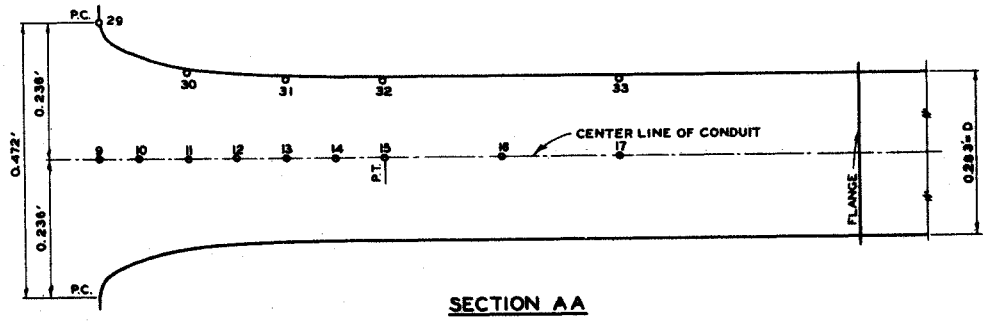
PLATE 14



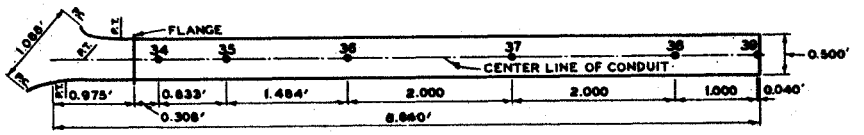
TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



SECTION AA



SIDE VIEW OF CONDUIT

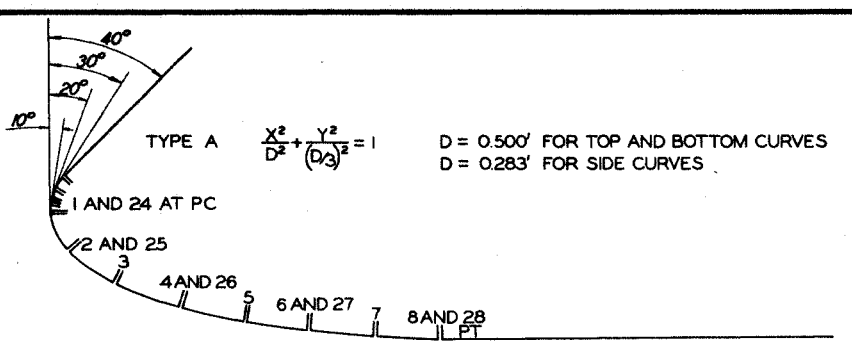
NOTES: DISTANCES SHOWN IN FEET

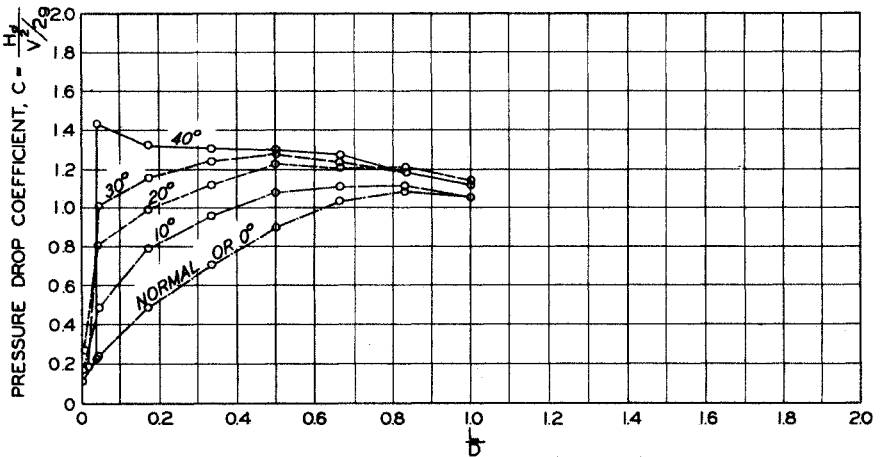
EQUATION FOR ALL CURVES $\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$

PIEZOMETER LOCATIONS

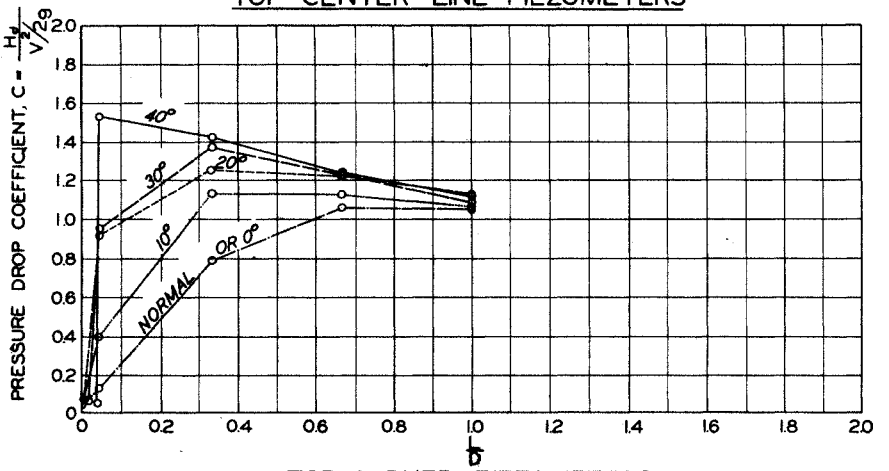
CONDUIT AXIS 40° FROM NORMAL TO FACE OF DAM

PLATE 15





TOP CENTER LINE PIEZOMETERS



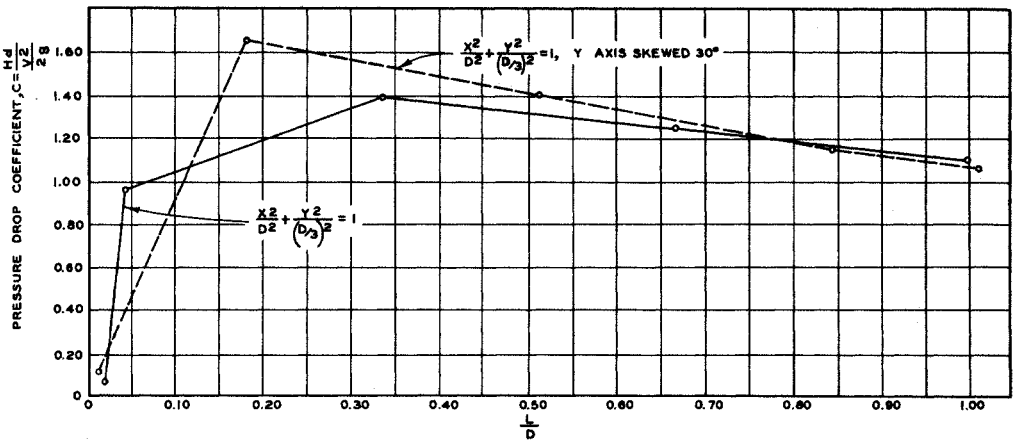
TOP CORNER PIEZOMETERS

NOTE: H_d = PRESSURE DROP FROM POOL TO PIEZOMETER.
V = AVERAGE VELOCITY IN CONDUIT PROPER.
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED.

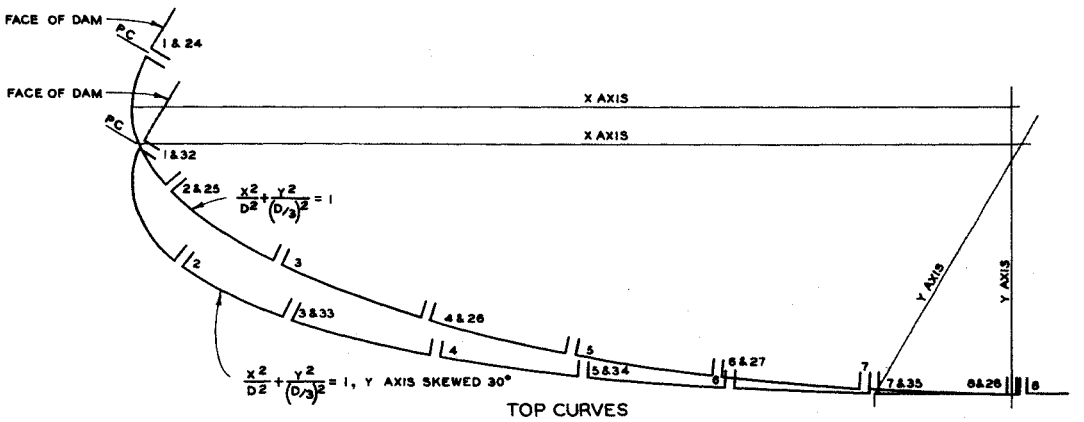
PRESSURE DATA

EFFECT OF ENTRANCE SLOPE
TOP ENTRANCE CURVES

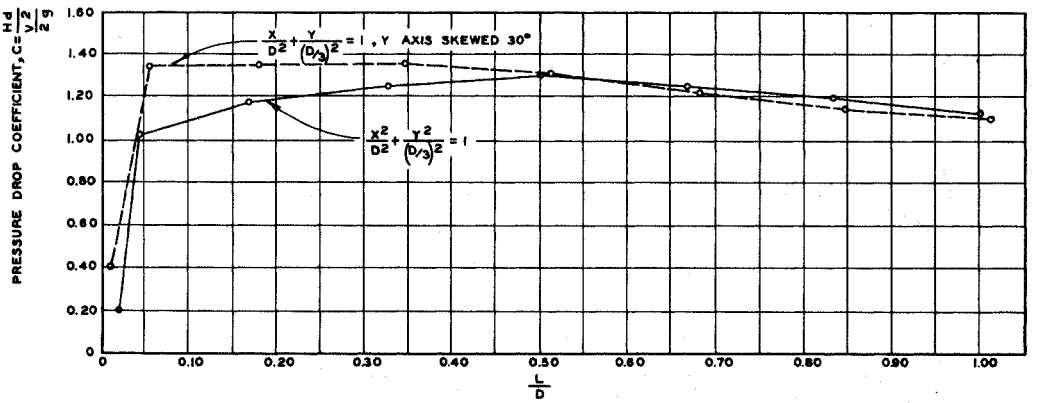
PLATE 16



CENTER LINE PIEZOMETERS



TOP CURVES



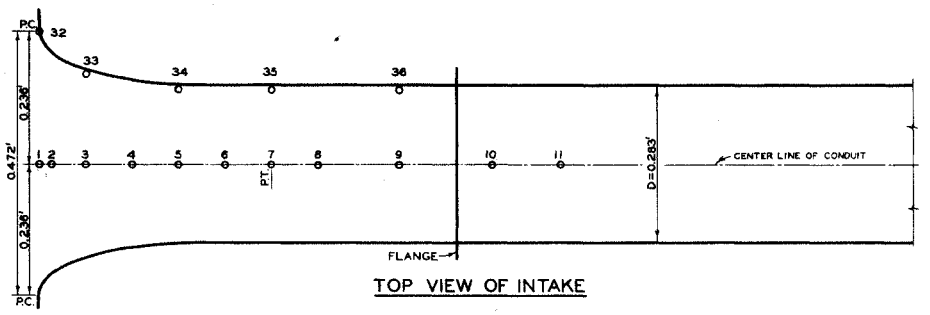
CENTER LINE PIEZOMETERS

NOTE: H_d = PRESSURE DROP FROM POOL TO PIEZOMETER.
V = AVERAGE VELOCITY IN CONDUIT PROPER.
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED.

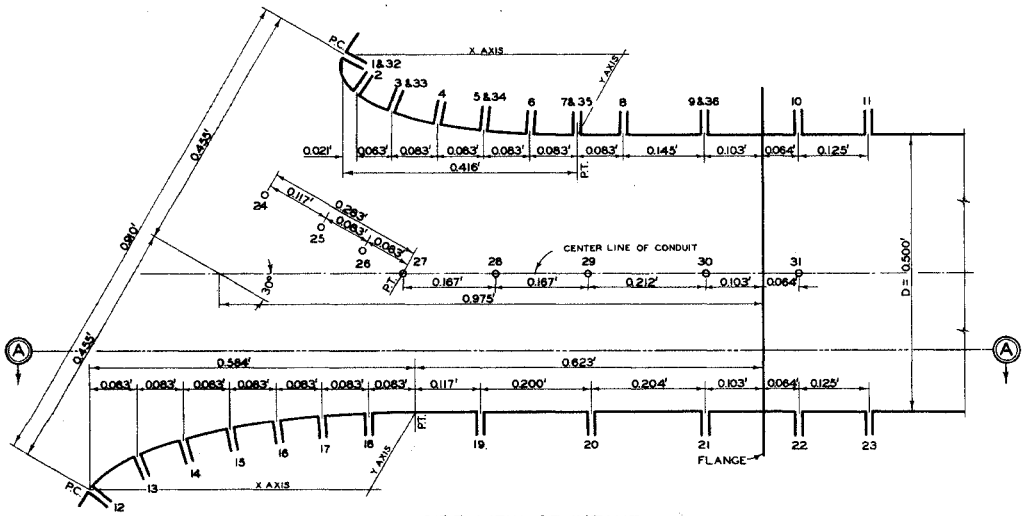
PRESSURE DATA

EFFECT OF SKEWING Y AXIS

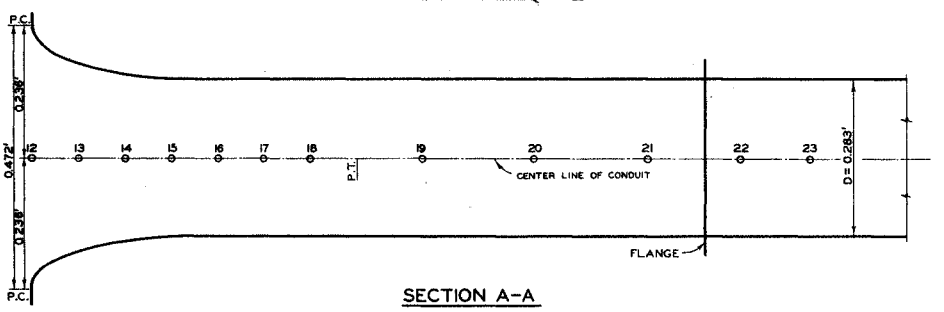
PLATE 17



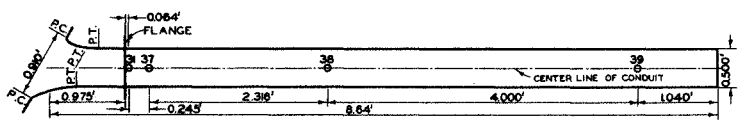
TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



SECTION A-A



SIDE VIEW OF CONDUIT

NOTES: DISTANCES SHOWN IN FEET.

EQUATIONS FOR ENTRANCE CURVES:

TOP & BOTTOM $\frac{X^2}{D^2} + \frac{Y^2}{(1.3D)^2} = 1$, D=0.50'; Y AXIS SKEWED 30°

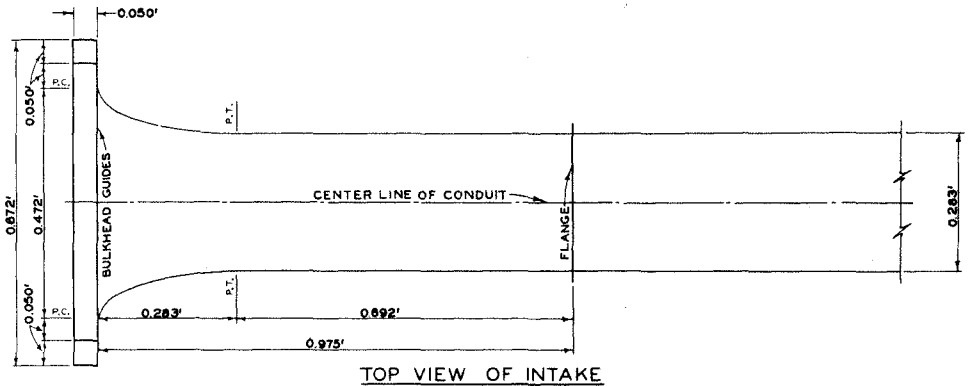
SIDES $\frac{X^2}{D^2} + \frac{Y^2}{(1.3D)^2} = 1$, D=0.283

PIEZOMETER LOCATIONS

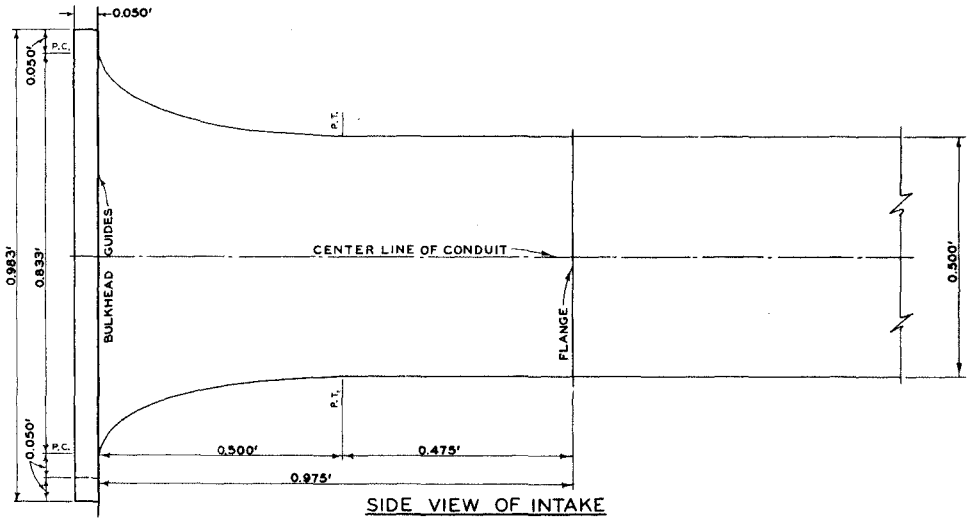
CONDUIT AXIS 30° FROM NORMAL TO FACE OF DAM

Y AXIS SKEWED 30°

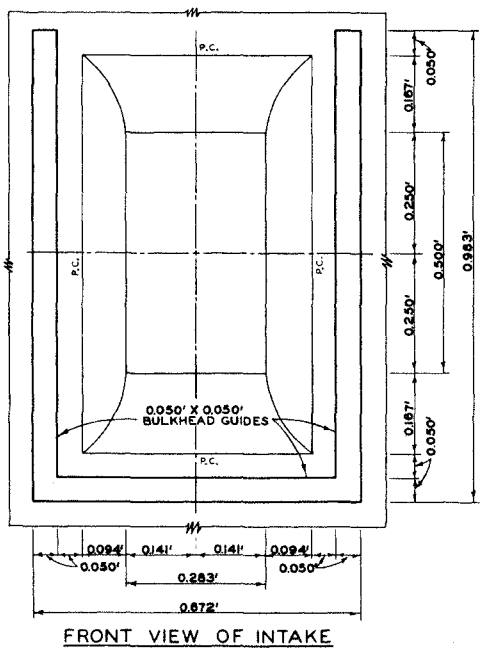
PLATE 18



TOP VIEW OF INTAKE



SIDE VIEW OF INTAKE



FRONT VIEW OF INTAKE

NOTE:

DISTANCES SHOWN IN FEET.

EQUATION FOR ENTRANCE CURVES: $\frac{X}{D^2}+\frac{Y}{(\frac{1}{3}D)^2}=1$

FOR LOCATION OF PIEZOMETERS SEE PIEZOMETER LOCATIONS PLATE 1.

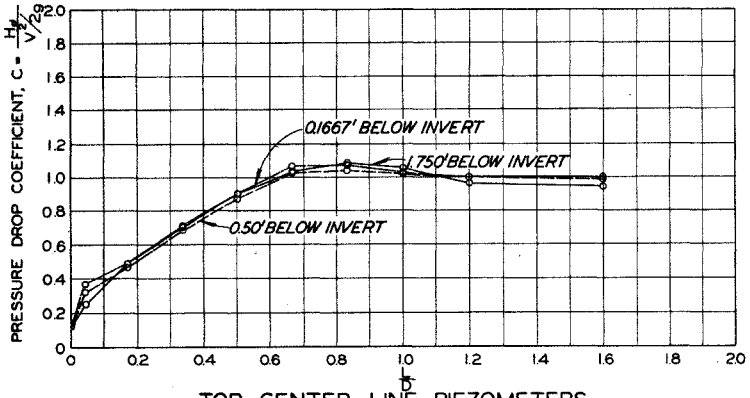
LOCATION OF BULKHEAD GUIDES

CONDUIT AXIS NORMAL TO FACE OF DAM

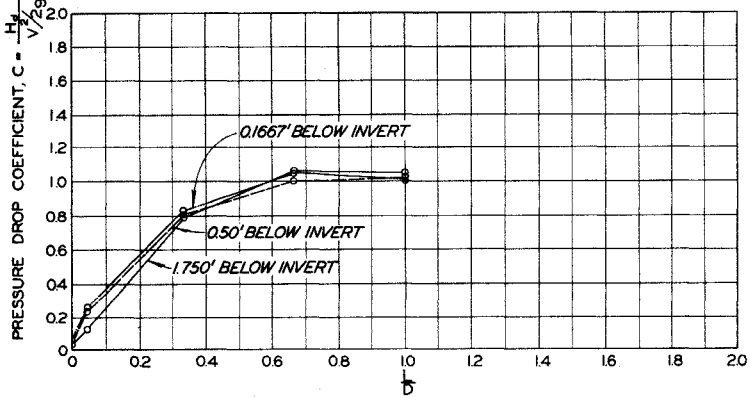
BULKHEAD GUIDES AT INTAKE

PLATE 20

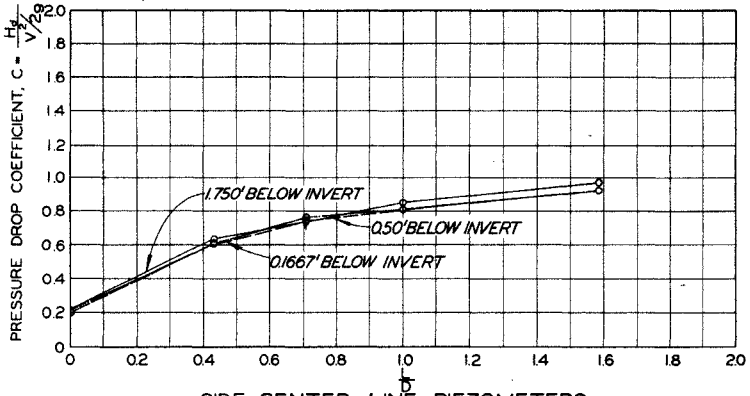
TYPE A $\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$ D = 0.500' FOR TOP AND BOTTOM CURVES
D = 0.283' FOR SIDE CURVES



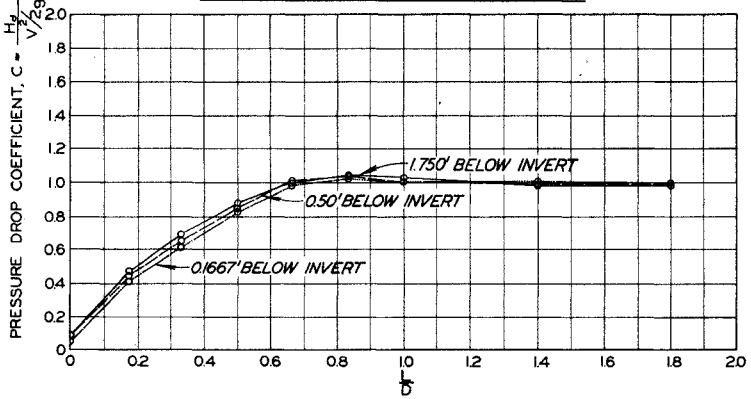
TOP CENTER LINE PIEZOMETERS



TOP CORNER PIEZOMETERS



SIDE CENTER LINE PIEZOMETERS



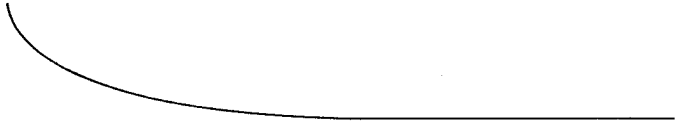
BOTTOM CENTER LINE PIEZOMETERS

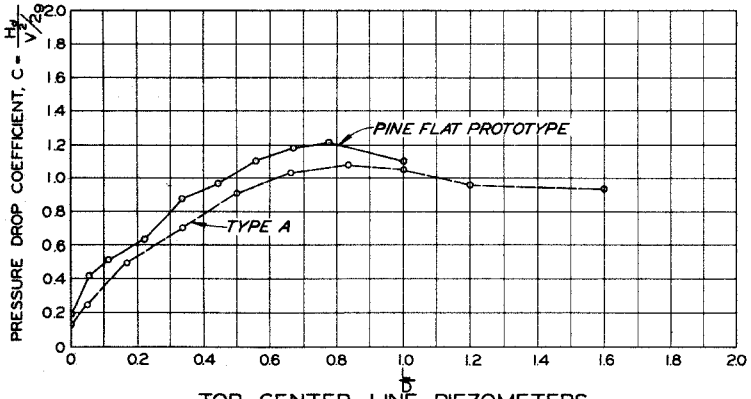
NOTE: H_d = PRESSURE DROP FROM POOL TO PIEZOMETER.
V = AVERAGE VELOCITY IN CONDUIT PROPER.
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED.

PRESSURE DATA

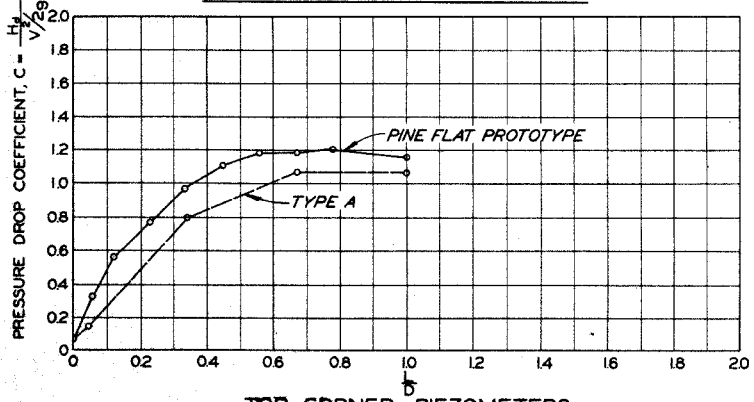
EFFECT OF VARYING DEPTH OF APPROACH

ENTRANCE CURVES $\frac{X^2}{D^2}+\frac{Y^2}{(D/3)^2}=1$ PINE FLAT CONDUIT 5 FT BY 9 FT.
TYPE A (PROTOTYPE EQUIVALENT) 5 FT 8 INCH BY 10 FT.

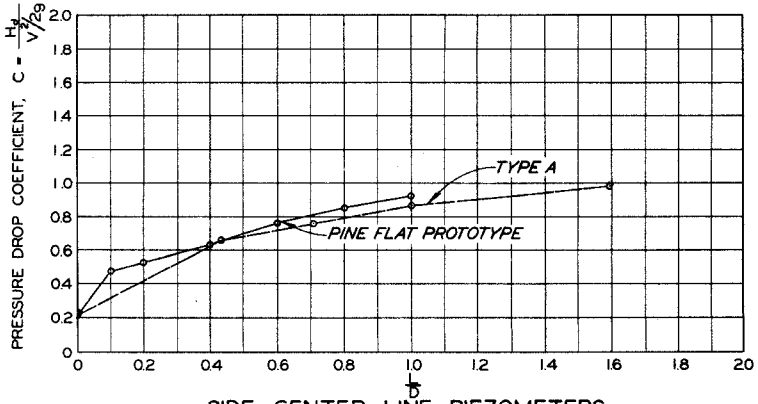




TOP CENTER LINE PIEZOMETERS



TOP CORNER PIEZOMETERS



SIDE CENTER LINE PIEZOMETERS

NOTE: H_d = PRESSURE DROP FROM POOL TO PIEZOMETER.
V = AVERAGE VELOCITY IN CONDUIT PROPER.
$\frac{L}{D}$ = RATIO OF DISTANCE DOWNSTREAM TO DIMENSION OF CONDUIT IN DIRECTION CONCERNED.

COMPARISON OF MODEL PROTOTYPE DATA
TYPE A VS PINE FLAT ENTRANCE CURVES

PLATE 21